

NOVEMBER 23, 1961

MACHINE

DESIGN

A PENTON PUBLICATION — BIWEEKLY

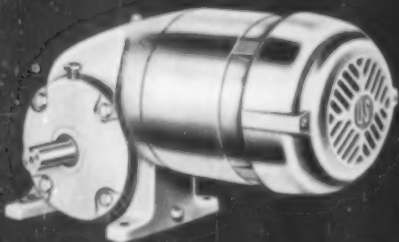
Y · SPEED · VIBRATION · SOUND · VELOCITY · COLOR · TEMPERATURE · GLOSS · BASIC · ACCELERATION · ALTITUDE · THICKNESS · LENGTH · WIDTH · ANGLE · ELECTRONIC · VISCOSITY · LEVEL · HUMIDITY · CONDUCTIVITY · FORCE · ROTATION · COUNTING · ACIDITY · LINEAR DISPLACEMENT · FLOW · SI · TURBIDITY · PRESSURE · VACUUM · GAS CONTENT · STRAIN · CONTROLS · DEW POINT · DENSITY · LIGHT ·

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MR. STEVENS RICE
UNIVERSITY MICROFILMS
313 N. FIRST ST.
ANN ARBOR, MICH.

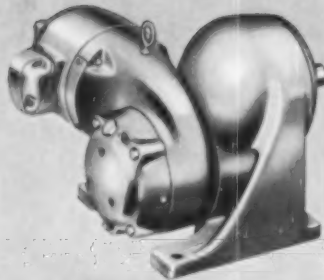
TAKENSWORTH

COMPACT, LOW-SPEED POWER...

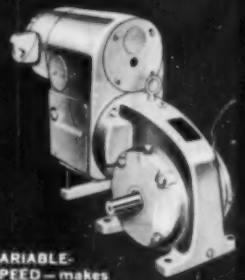


TOTALLY ENCLOSED—for corrosive dust, salt, spray and other damaging environments—provides slow speeds for applications in which ordinary motors require frequent replacement.

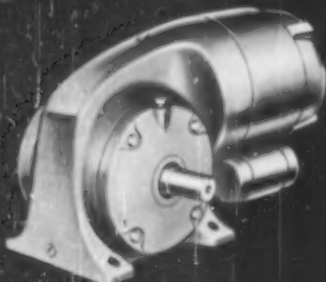
EXPLOSION-PROOF—for volatile fumes, explosive dust atmospheres—provides genuine explosion-proof characteristics for hazardous environments. Underwriters' Laboratories approved for Class 1 Group D and Class 2 Groups F and G.



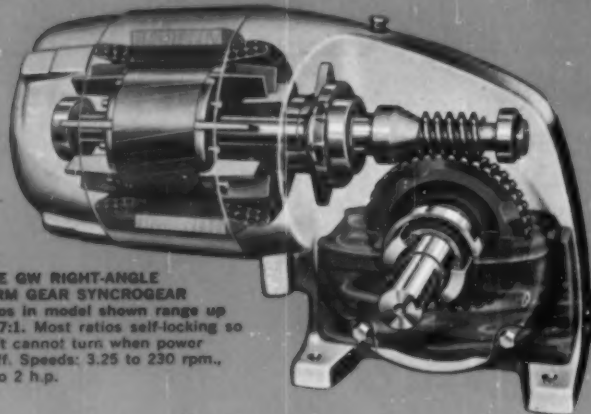
DOUBLE-REDUCTION (GWB)—ratios up to 354:1—with second stage helical gear train—provides steady, multiplied torque and extremely slow speeds for applications in which power-speed precision is important. High-torque case is constructed to resist extra pull.



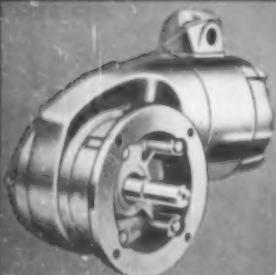
VARIABLE-SPEED—makes instant speed changes by merely turning dial—Combination of GW Syncrogear with U.S. Vari-drive Motor to provide speed control with worm gear reduction.



SINGLE PHASE (GWR)—can be connected to any 110 or 220 volt line—equipped with capacitor. Single phase is available from $\frac{1}{8}$ to 1 $\frac{1}{2}$ h.p. Single phase is also available in double reduction. Type GWB-R.



TYPE GW RIGHT-ANGLE WORM GEAR SYNCROGEAR
Ratios in model shown range up to 87:1. Most ratios self-locking so shaft cannot turn when power is off. Speeds: 3.25 to 230 rpm., $\frac{1}{8}$ to 2 h.p.



FLANGE-MOUNTED (GWV)—for direct connection to driven machine—Footless. Can be direct-connected vertically or on side with shaft right or left.

U. S. SYNCROGEAR /right-angle, worm-gear type

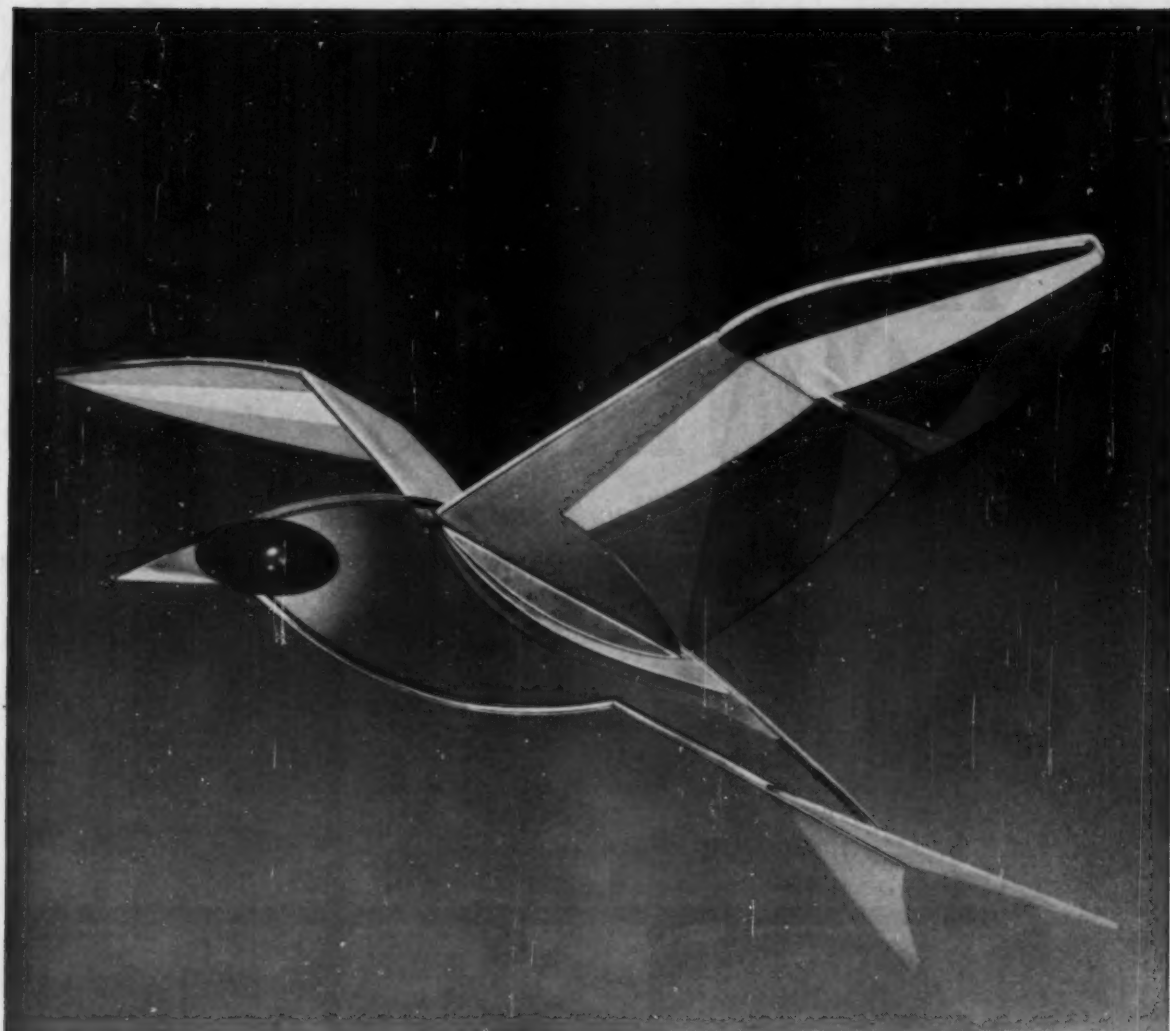
The most economical gearmotor is the right-angle worm-gear type, and it is often the most logical choice for compactness. U. S. SYNCROGEAR MOTORS, Type GW, offer you such features as compact, strong pyramidal construction and rugged cast-iron case, providing rigidity to handle overhung loads, high starting torques; U. S. Motors' own precision-made gears; one-piece motor worm-gear shaft eliminating connection of motor and worm shafts; and no-rib construction for easy cleaning. Available $\frac{1}{8}$ to 2 h.p. For trouble-free operation... long life... specify: U. S. SYNCROGEAR MOTORS, RIGHT-ANGLE WORM-GEAR TYPE.

U.S. ELECTRICAL MOTORS INC.

Los Angeles 54 (P.O. Box 2058), California — Milford, Conn.



Free illustrated brochure... send for No. F-1971



Sculpture created especially for 3M Company by Guy Palazzola

FEATHER-LIGHT...

3M Adhesives help take pounds off today's metalworking products

Reducing dead weight can give a product extra sales advantages . . . make it easier to handle and assemble . . . lower shipping and production costs. The answer: Fabricate with 3M Industrial Adhesives and save weight without sacrificing strength.

In fact, 3M Adhesives often substantially increase the strength of an assembly by distributing stresses evenly over a wide area, making lightweight, high-strength designs possible. And without mechanical fasteners that lower the integrity of the material and cause stress points that tear, fabricators can substitute lighter gauge materials.

For example, 3M Adhesive EC-1357—only one of a complete line of strong, general purpose industrial adhesives—finds wide application in products requiring strength and light weight. It is used in the bonding of metal frames to veneered

plywood . . . in honeycomb construction for table tops . . . in sandwich-type wall panels, where it bonds porcelain enameled steel to an expanded glass core.

Backed by a quarter century of research, 3M Technical Service is solving fabrication problems for leading manufacturers in various industries. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, look first to 3M. Write AC&S Division, 3M Company, Department SBR-81, St. Paul 6, Minnesota.

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ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

...WHERE RESEARCH IS THE KEY TO TOMORROW



What do you want to bond to what?

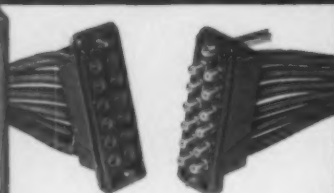
The Bird is fabricated of these materials and bonded with a variety of 3M Adhesives:

1. Stainless Steel 2. Wood 3. Plastic 4. Glass 5. Brass.

COAX HYFEN[®] CONTACTS

*reliable solderless contacts
result in dramatic
reduction of
installation time*

wide application—all with snap-locked removable contacts



Type MB-X

Coax in miniature rectangular configurations.



AQUALOK T.M.

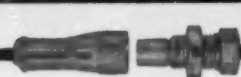
Weather-sealed round connector—either all coax or in combination with single conductors.



Coax

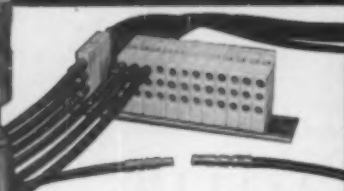
Bantam HYFEN

Connectors for standard and miniature coax—either all coax or in combination with single conductors.



Coax Feed-Thru

Miniature and standard connector (above) and splice (below). All plastic shells—lightweight, durable, impact resistant.



Coax MODULOK[®]

Modular terminal block with spring-loaded removable contacts.



Type PD-X

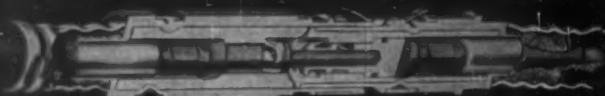
Modular HYFEN inserts for all standard or miniature coax or in combination with inserts for single conductors.



Type ME-X

Rack and panel HYFEN series—features one piece shell, one piece inserts.

Burndy's coax contacts, for both miniature and standard coax cable—feature crimped inner and outer contacts, which provide a more reliable connection, faster and easier. High speed production tooling results in low installed cost—crimps contacts in any circumferential position. Few parts simplify installation. No heat to damage insulation.



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Front Cover: This issue's cover by George Farnsworth emphasizes the startling number of applications to which transducers can be put. On Page 139, authors Ruiter and Murphy go into detail on the subject.

November 23, 1961

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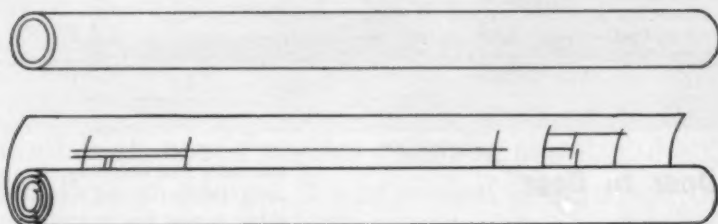
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DESIGN ENGINEERING NEWS



Air Car Flies Door to Door

GEORGETOWN, ONT.—A spin-proof, stall-proof aircraft that can take off from one back yard and land in another promises to ease future rush-hour traffic problems. Called Avian 2/180 by its designers, Avian Aircraft Ltd., the rotary-wing gyroplane can jump off a 10-ft square plot of ground.

Developed for business and pleasure uses, the craft is said to combine the best features of the helicopter and the autogyro. Like the latter, it uses a free-wheeling rotor, but the rotor incorporates advances made during development of modern types of helicopters.

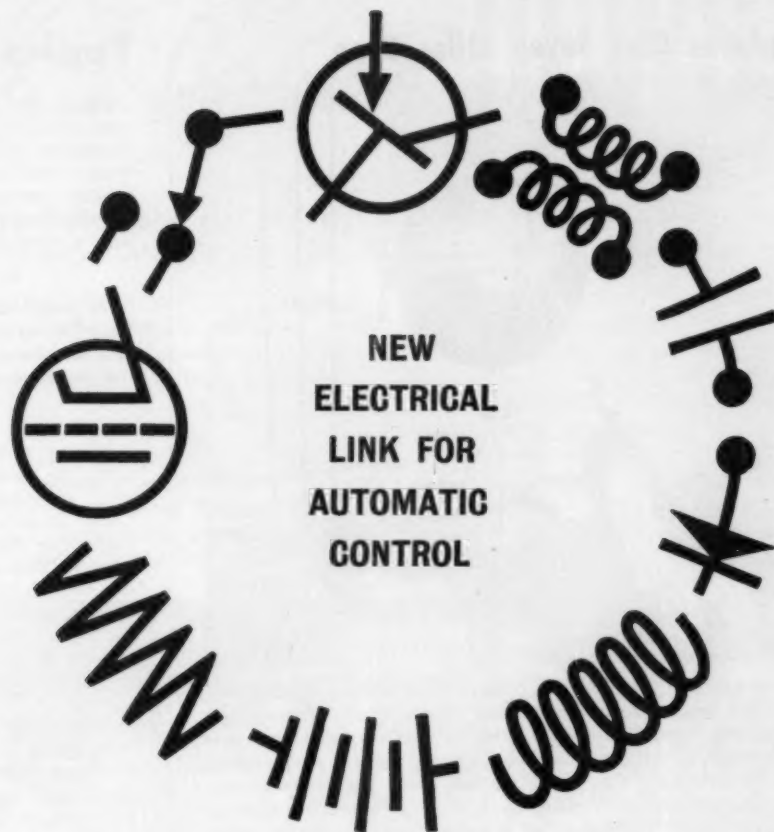
Rotor blades have a high degree of stiffness, and a strap system permits blade flapping and torsional modes. According to the company, this design eliminates drag hinges and the associated troublesome dampers. Even under the most arduous operating conditions, the blades never go out of the track. Problems of ground resonance have been completely eliminated.

The small-diameter ducted propeller allows the rotor to be placed near the fuselage, improving stability and reducing overall height of the aircraft. Having a high static efficiency and producing high thrust, the propeller acts as a stabilizing unit in forward flight. The rudder is mounted in the rear section of the duct.

The aircraft measures 16.2 ft long by 8.6 ft high. Gross weight is 1720 lb, of which 600 lb can be useful load. Cruising speed is 130 mph, and range in still air (fuel tank holds 31 gal of gasoline) is 480 miles. Service ceiling is 17,000 ft.

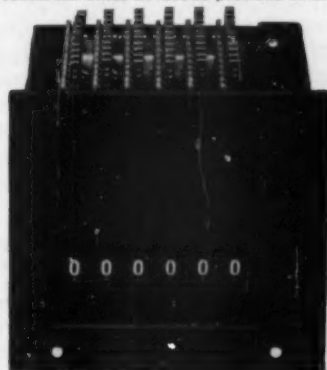
Normally free wheeling, the rotor can be mechanically linked to the engine for jump take-offs. When brakes are on and rotor pitch lever is at its lowest point of travel (zero incidence of the blades), opening the engine throttle accelerates the rotor to a predetermined speed. Increasing the rotor pitch breaks the mechanical-drive connection and provides a positive angle of incidence for the rotor blades. The blades bite the air, lifting the aircraft vertically off a 10-ft square field.



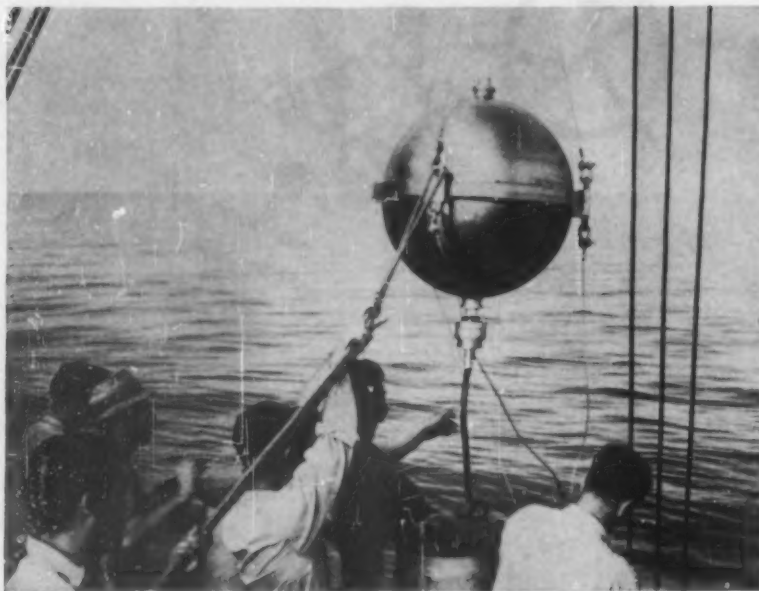


New Veeder-Root high speed digital readout counter meets new needs in automation and system design. It's precision engineered to record, display and electrically transmit accumulated digital levels. More than that, it's a fresh approach to a widening range of automation needs... an ingenious electrical link for digital indication, data recording, storage and transmission, automatic sequencing, predetermining control. See what this versatile unit can do for your equipment or designs. Write Electrical Section, Veeder-Root Inc., Hartford 2, Connecticut. **count on... VEEDER-ROOT**

Series 1744 High-Speed Digital Readout Counter saves time and labor by eliminating manual counting and recording of production. It counts twice as fast, resets ten times as fast as previous units.

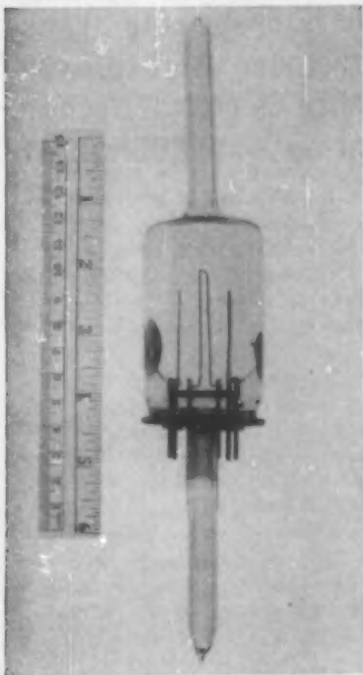


Instrument Spheres Dive Seven Miles Deep



Squeezed by pressures exceeding 16,000 psi, stainless-steel spheres loaded with sensitive instruments are investigating the deepest ocean floors. Because salt water under high pressure intensifies normal corrosion (and corrosion generates stray electric currents which affect instrument readings) the spheres are designed to be as rustproof as possible. Fabricated for the Navy by Baldwin-Lima-Hamilton Corp., Philadelphia, the 30-in. diam by 1-in. thick vessels are sunk by tied-on bags of gravel. They stay down for a preset time, coming up when explosive charges in the anchor couplings release the gravel. Oil-filled flotation bags furnish the buoyancy for the trip back to the surface. Part of the Deep-Dip project, the spheres allow the Navy to make magnetic, electromagnetic, radioactivity, and acoustical measurements on the bottoms.

Disposable Vacuum Pump Has Three-Way Action



HICKSVILLE, N. Y. — A vacuum-tube-like device, called the Titanium Ion Pump, combines electrical and chemical reactions to provide a vacuum of better than 10^{-9} mm Hg. Developed by Ampere Electronics Corp., the disposable unit will evacuate electron tubes or other vacuum devices of comparable size.

Two cathodes (inverted-V type) are incorporated on each side of the anode, a square loop of tungsten wire. One cathode consists of a single loop of tungsten wire wound with titanium. During operation, titanium evaporates and is deposited on the inside of the envelope. Gas is absorbed within the pump by three simultaneous processes:

- Chemical reactions between the gas and the titanium getter.
- Forced combination of titanium atoms with evacuated gas particles.
- Occlusion of gas particles in successive layers of titanium.

Topics

Silence may indeed be golden for some inventor. The London Noise Abatement League and a group of British manufacturers, looking for a noiseless pneumatic drill, feel that manufacturing rights to such a device will be worth \$280,000.

• • •

No lunar loitering: Present NASA plans for the Apollo program call for only four hours of exploration by the first American moon visitors.

• • •

Hearing yourself sing is possible with the new Choralier portable stereo phonograph made by Admiral Corp. It comes with a lightweight microphone that can be plugged into a special "sing-along" jack. Sound from the microphone comes out the right speaker cabinet, and the record on the phonograph's turntable is heard through the left speaker.

• • •

Bashful babies, reluctant to announce their needs, will welcome a newly developed diaper cover. Fitted with wires and transistors, it sounds a buzzer alarm when dampness is detected.

• • •

A better-smelling mousetrap eliminates the need for baiting. The trigger, molded of Eastman's Tenite butyrate plastic, has a "locked-in" scent which is said to be irresistible to rodents. However, McGill Metal Products Co., the builder, also provides a bait holder for the sake of humans (and perhaps mice) who don't trust the scent.

• • •

The safest vehicles for humans to travel in are rockets, observes the October MIT Newsletter. At present, casualties per passenger mile are zero.

• • •

Who wipes the windshield isn't indicated, but a recent products list circular from the Small Business Administration mentions a gasoline vending pump which accepts either coins or credit cards.

• • •

Eighteen hundred tons of steel are moved every time the button is pushed to open or close the roof of Pittsburgh's new civic auditorium. The six leaves that make up the roof, driven and controlled by Westinghouse equipment, begin opening or closing at about the same time; they travel at different speeds so that they all arrive at the desired spot in $2\frac{1}{2}$ seconds.

Fluid Power news



From Oilgear Application-Engineering Files

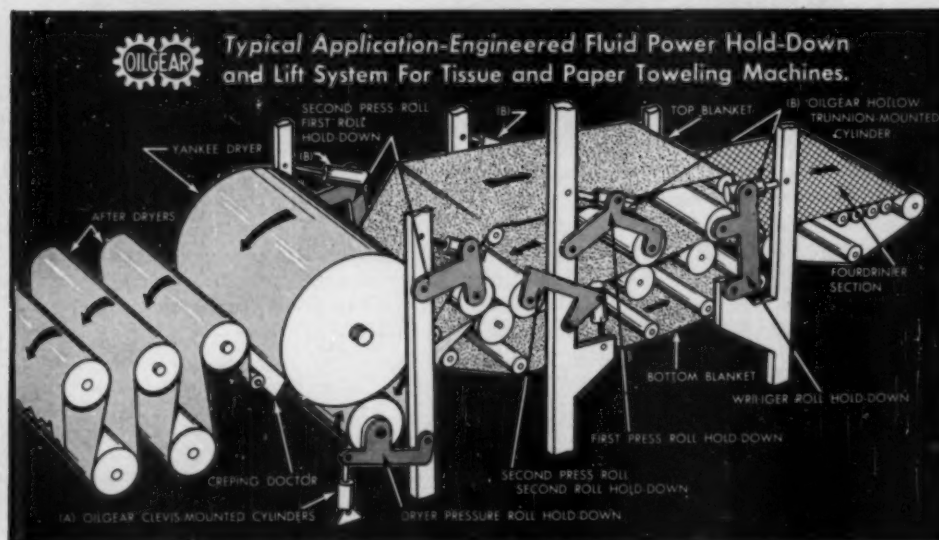
HOW OILGEAR HOLD-DOWN AND LIFT SYSTEMS INCREASE ROLL LIFE—IMPROVE PRODUCT QUALITY

USER: Scott Paper Company, Chester, Pa.; Everett, Wash.; Mobile, Ala.; Fort Edward, N.Y.

PROBLEM: To supply hold-down and lift systems for rolls on paper machines, paper coating machines, super calendars, laminating and similar processing machines—that can be accurately controlled from a simple remote control panel.

USER REQUIREMENTS: 1. Provide constant, uniform, pre-set roll pressures. 2. Smooth lowering and/or forcing of pressure rolls downward to avoid damage, such as fracturing or flattening. 3. Fast, easy, positive selection of such functions as "Lower," "Hold Down," "Release,"

"Lift," "Hold Up," "Off." 4. Accurately, infinitely vary the pressure on either end of each roll independently over a wide range, at any time, to balance the opposing forces created for most efficient machine operation and product quality. 5. A direct-reading, constant, visual indication of the pressure and force exerted on either end of each roll. In addition, the systems must be simple . . . clean . . . easy to install and maintain . . . facilitate replacement of worn rolls . . . trouble-free, dependable, heavy-duty, for continuous, 'round-the-clock operation.



SOLUTION: Oilgear Application-Engineered Hold-Down and Lift Systems consisting of Oilgear Heavy-Duty, Constant or Variable Displacement Pumps that supply Fluid Power to Oilgear "Custom-Quality" Cylinders through separate Oilgear Valves on a remote control panel—provide smooth, positive motion and steady, pre-set holding pressures. Cylinders can be mounted directly, or through mechanical linkage, to pressure roll bearing ends. Simplicity of pump drive and installation keep machine cost at a minimum. Remote Control Panel provides fast, positive selection of all functions—operator can "Lift," "Hold Up," "Release," "Lower," "Hold Down"—at any time; accurately, infinitely vary pressure on either end of each roll independently, and have constant, direct-reading, visual indication of pressure and force being exerted at bearing ends of each roll.

ONE USER STATES—"The control panel indication is so accurate that a worn, 'off-balance' or out-of-round roll can be readily detected."

Another User Reports—"Oilgear is far superior to other systems . . . direct gage readings have enabled us to experiment with varying degrees of pressure on the rolls, so that we can operate with less pressure than we hitherto thought feasible. This has resulted in improved product quality and longer roll life."

Top Photo: One of the Oilgear Hold-Down and Lift System Control Panels as installed with each of Scott Paper Company's two, new tissue machines in their Southern Division Mill, Mobile, Ala.—symbolized in the schematic drawing, left. Daily production from these machines averages 200 tons of Scott's bathroom tissues, toweling and wipers for household and industrial use. Right: A typical Oilgear Heavy-Duty "Power-Pak"—Variable Displacement Pump, electric motor drive, and reservoir base—used with Hold-Down and Lift Systems.

Oilgear is no "stranger" in the paper industry . . . other Oilgear Linear Drives are in operation on pulp log splitters and pulp baling presses. Similarly, the highly efficient, long-life, Oilgear Heavy-Duty Variable Speed Rotary Drives are compiling enviable records on special purpose paper machine sections . . . on complete paper machines . . . on multi-color printing press drives . . . or unwinder and winder drives . . . on laminating and coating machine drives. It's well worth your while to consider Oilgear—"for the lowest cost per year!"

For practical solutions to YOUR linear or rotary motion problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

THE OILGEAR COMPANY

Application-Engineered Fluid Power Systems

1568 WEST PIERCE STREET • MILWAUKEE 4, WISCONSIN
Phone: Mitchell 5-6715 . . . Direct Distance Dialing Code—414

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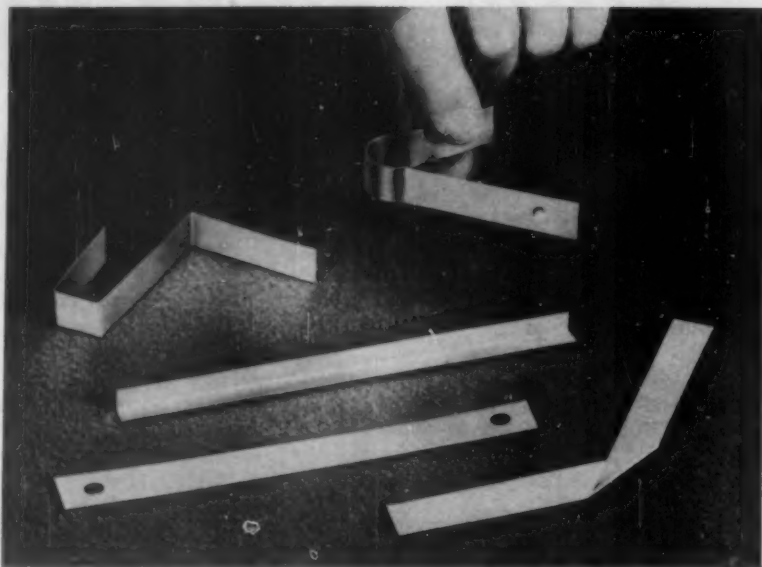
Pure Cobalt Develops Ductility

TORONTO, CANADA — Pure cobalt with good ductility and workability can now be produced by powder rolling. Twice as strong as nickel, it keeps its strength at high temperatures, resists corrosion, and has excellent magnetic properties. Available in coiled-strip form in thicknesses ranging from 0.005 to 0.025 in., pure cobalt could now become an important design material.

Previously, cobalt has lacked properties essential in metalworking applications. The new strip, developed by Sherritt Gordon Mines Ltd., is considerably more ductile, chiefly because it has a higher degree of purity. SGM rolls the metal directly from powder, and the end product is 99.9 per cent pure.

Mechanical properties of the strip can be adjusted by heat treatment. When cold rolled to a 25 per cent reduction, for example, the material has a tensile strength of 165,000 psi, elongation of 0.5 per cent, and Rockwell hardness (45T) of 85. In the annealed condition, tensile strength, elongation, and hardness are 115,000 psi, 15 per cent, and 68, respectively.

Difference in strip properties depends on crystal structure. There



New cobalt strip can be easily formed by conventional metalworking methods. Parts shown were bent to right angles with and against the grain, punched, sheared, and slitted. A small bubble was added to the one being held.

are two crystal forms: Close-packed hexagonals at temperatures up to 785 F, and face-centered cubics above this temperature. When the strip is cooled after heat treatment above 785 F, transforma-

tion to the low-temperature phase is sluggish. The result is a mixture of crystals. The type of heat treatment and the eventual proportion of the two crystal phases determine ductility.

Armed Forces List Needed Inventions

WASHINGTON—Hoping to learn of new leads and developments which may not be known to government researchers, the National Inventors Council, U. S. Dept. of Commerce, has drawn up a 104-page list of new devices needed by the Armed Forces. Civilian inventors are invited to try fresh approaches, ideas, and techniques to come up with new equipment designs.

In the report, blue-sky inventions (such as a new kind of barrier that would halt, delay, or divert an enemy) are called for, but so are hardware developments:

- Fastener system that would act as a bolt or cap screw and operate with very little turning. The principle might be applied as the basis for a gun breech to replace sliding and rotating breech blocks.
- Throttling device which could produce a desired pressure differential independent of throttling velocity, density, and viscosity of the fluid.
- Carburetor or air-intake system that

would prevent carburetor icing on 375, 500, and 800-hp gasoline engines.

Some of the inventions requested are even more basic:

- Hydraulic valves that are immune to dirt.
- Greaseless ball bearings suitable for use at 650 C. Bearing sizes would range from 200 series to 206 and larger. Operating conditions would vary from 10,000 to 100,000 constant rpm, and from 75-lb-radial, 25-lb-axial loading on up.
- High-temperature seals that could operate under both static and dynamic conditions at pressures ranging from 25,000 to 60,000 psi.

Many of the wanted inventions would influence the design of civilian vehicles:

- High-speed tracks for earth-moving equipment. They would be capable of operating for 20,000 miles at 5 mph; 5000 miles at 25 mph.
- Glareless headlights.
- Ignition systems that will not foul

spark plugs. The plugs would be replaced only when the engine is overhauled.

- Electric starters, generators, batteries, coils, and distributors capable of starting and maintaining ignition when gasoline and diesel engines are submerged in salt water.

New vehicle drive systems are also called for:

- Starting motor engagement drive which operates from -65 to 125 F, requires no change of lubricant or special servicing during the life of the engine.
- Constant-speed generator that could be used on variable-speed (automotive) engines.

An inventor who thinks he has a solution to any of the equipment-development problems should write to the National Inventors Council, Office of Technical Service, Dept. of Commerce, Washington 25, D. C. Copies of the complete report *Inventions Wanted* are also available at the same address.

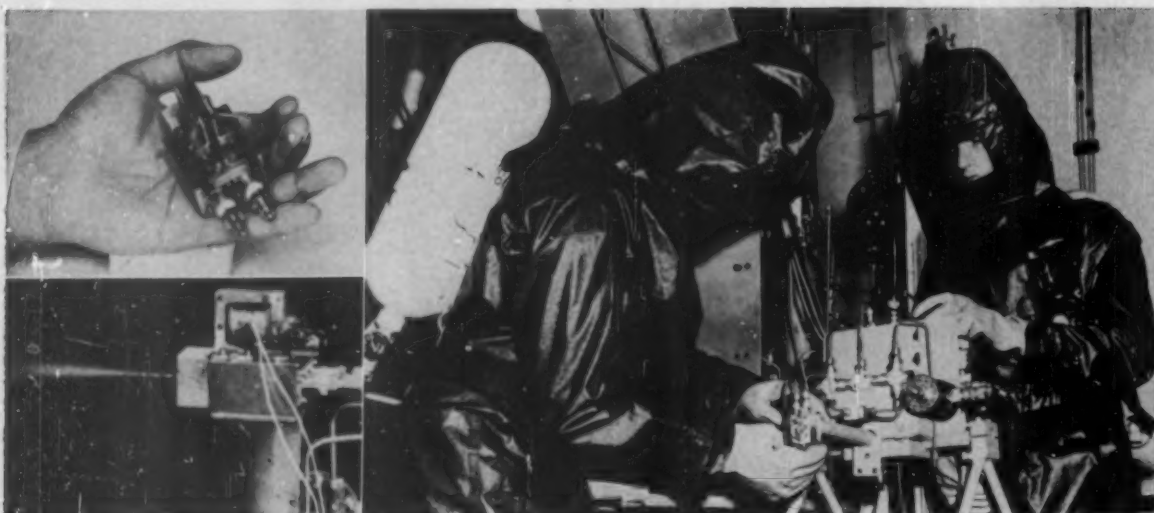
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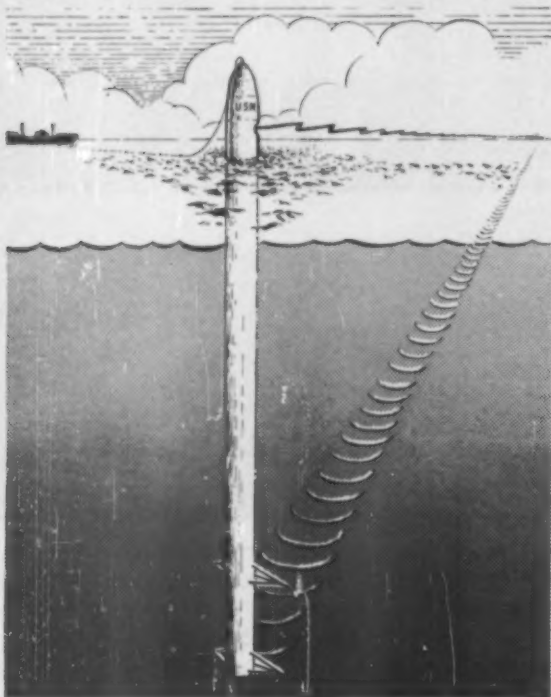
Control-Rocket Package Generates 1-lb Thrust



Solenoid, bipropellant valves, and thrust chamber are combined in one compact unit in a new control rocket developed by Vickers Inc., Div. of Sperry Rand Corp. The pulse-modulated device, called a significant advance in space-vehicle control equipment, uses a bipropellant combination—nitrogen tetroxide (oxidizer) and hydrazine/unsymmetrical dimethyl hydrazine (fuel). This combination was selected in anticipation of future requirements for satellite and space-vehicle

reaction controls. Combustion occurs spontaneously when propellants contact the oxidizer; no external igniter is needed. The model developed for vernier attitude corrections (left) has a pulse-modulated thrust level of 1 lb. Highly reliable and efficient, it requires only a few watts of input power, and its response time is on the order of milliseconds. While the fuels are storable, they are also self-igniting, and extreme care is taken while fueling the rocket (right).

Spar to Probe Oceans' Acoustic Secrets



In listening position, SPAR will receive both underwater sonar signals and radic signals from transmitting research ships. The tending towship will be leashed to the cylinder by a half-mile of tow and power-supply cables.

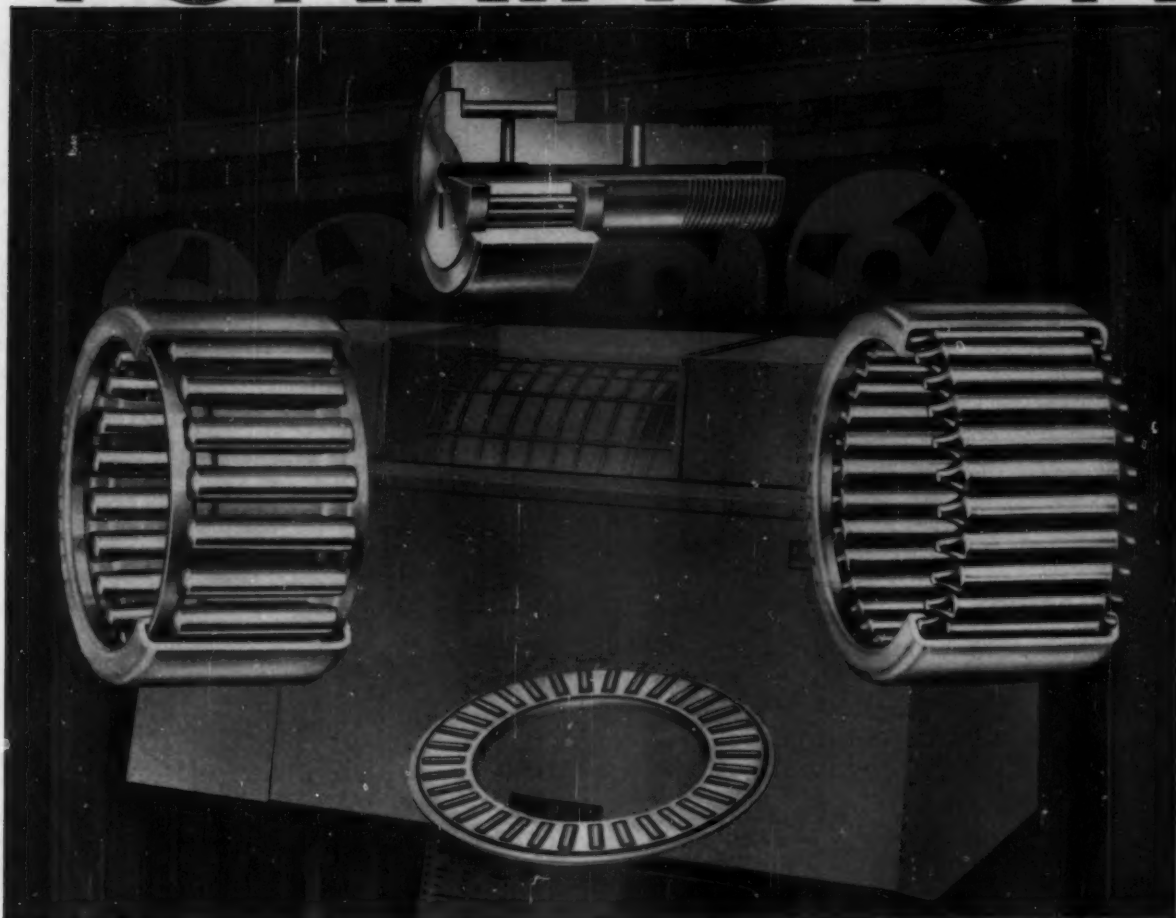
WHITE OAK, MD.—The U. S. Navy is developing a 350 ft long steel tube that will float horizontally on the ocean or pivot near one end to become a stable, vertical platform. Designed for acoustics research, the 16 ft diam cylinder will be towed all over the high seas and swung into position at different points to measure speed and intensity of underwater sound transmission.

Now under development at the U. S. Naval Ordnance Laboratory, the instrumented research vessel is called SPAR—Seagoing Platform for Acoustics Research. Sensitive underwater listening devices, thermometers, pressure gages and instruments for determining the amount of salt in the surrounding sea will be attached to the exterior of its hull. Ballast and free-flood tanks will make up the interior of a 280-ft section; operating machinery and additional instrumentation will be housed in a 70-ft buoyancy chamber.

The tending towship will remotely flood the rear of the vessel to make it swing down. Settling in the water like an iceberg, the craft will carry hydrophones and other external instrumentation to depths of 300 ft. SPAR will float vertically with only 50 ft of its buoyancy section protruding above the surface.

All research data collected with SPAR will be relayed to the tending ship by way of electrical cables linking the two vessels. In vertical position, SPAR will be so stable in the water that a vertical velocity of less than 1 fps is expected. The low velocity is necessary to reduce acoustical background interference caused by water around the hydrophones.

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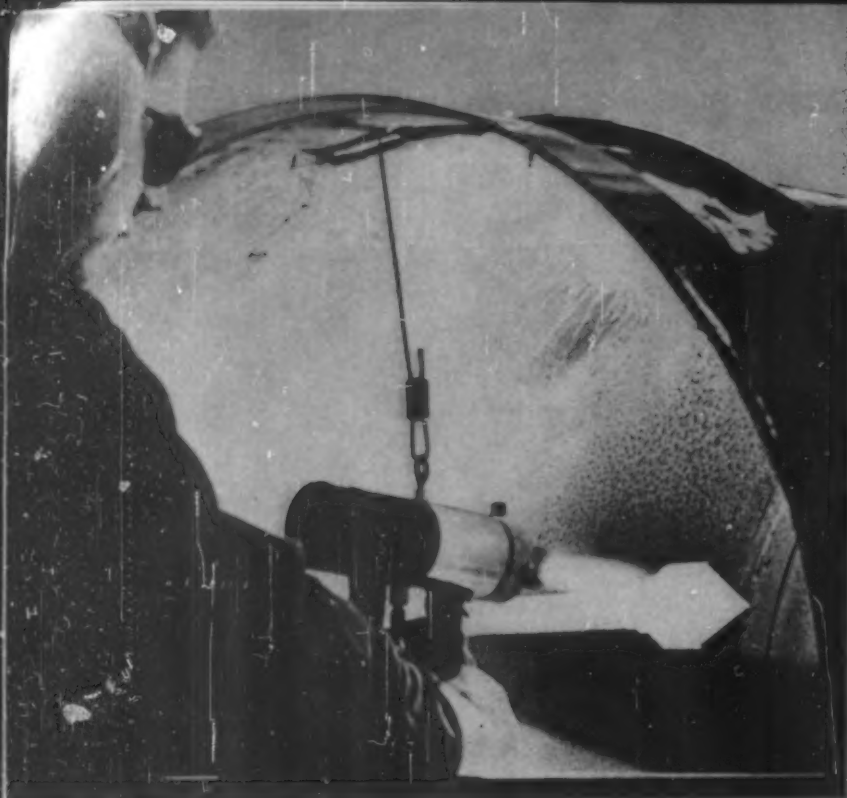
- ☐ Duplicator feed rolls
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- ☐ Punched card sorting drive rolls
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Beryllides Breach the Heat Barrier

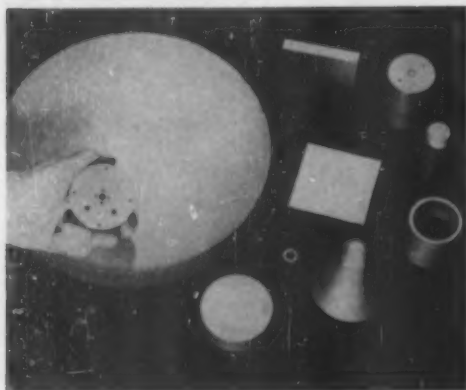
CLEVELAND—A new family of missile materials, developed by Brush Beryllium Co., retains structural strength and resists oxidation at temperatures up to 3000 F. Called beryllide intermetallic compounds, the "alloys" combine the most favorable high-temperature properties of superalloys, refractory metals, and ceramics, and they are almost as light as aluminum.

Made by chemically combining beryllium with one of the refractory metals, the beryllide compounds include good thermal conductivity and high heat capacity among their useful properties. None melt at temperatures below 3070 F (most have considerably higher melting points) and their thermal-expansion characteristics are comparable to those of nickel. They will resist 2700 F for 100 hr or longer, 3000 F for 10 hr, and are completely compatible with other materials used in spacecraft structures.

According to Brush, other materials being considered for high-temperature use can't match the beryllides:

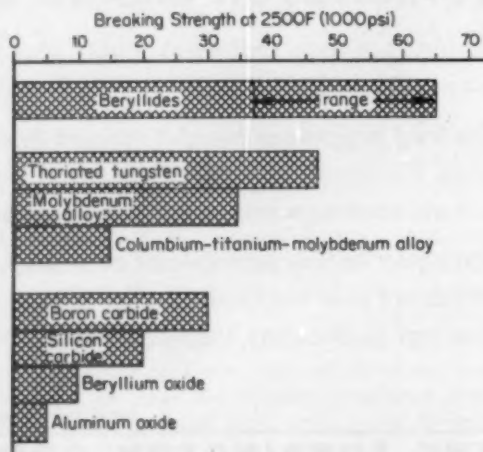
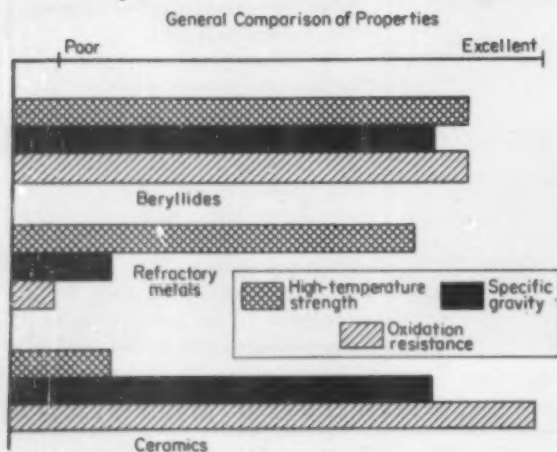
- Superalloys with cobalt, nickel, and columbium bases are currently

News Report



Feeding tantalum-beryllide powder into a plasma-flame spray, Brush technician forms a thin conical shape. The flame spray, at a temperature of 30,000 F, melts the powder and deposits it on a rotating conical form.

Parts fabricated from the beryllides vary in size and shape. The large disc was formed by pressing powder at high temperatures; smaller flat shapes were cold pressed and sintered. Casting is also possible.



limited to use at 2200 F and below. At higher temperatures they lose their strength and lack resistance to oxidation.

- Refractory metals, especially tungsten and molybdenum, must either be coated with a protective material or used in an inert atmosphere because they lack resistance to oxidation. Strength of the refractories does not exceed beryllides at 2500 F. The weight factor favors beryllides by a wide margin.

- Ceramics can be used at higher temperatures, but the beryllides are more than ten times stronger within their own temperature range. In addition, thermal conductivity of the beryllides is roughly twice that of the best ceramic material. Weight and oxidation resistance are comparable.

Shapes are now being commercially fabricated from two tantalum-beryllide compounds— $TaBe_{12}$ and Ta_2Be_{17} . These two are to be joined by five more that show promise—two zirconium and three niobium beryllides.

First reports on the high-temperature potential of the materials went to the Air Force in early 1960. Since that time, Brush researchers have been working out ways to fabricate the compounds.

Development of fabricating techniques is proceeding, and the two beryllides now being introduced will be available in a wide variety of forms. In addition, other beryllides are about ready to make their appearance, and Brush researchers are initiating a study of ternary systems—intermetallic compounds made by reacting a third metal.

Property Ranges for the Beryllides

Melting Point (°F)	3070-3610
Density (gram/cu cm)	2.72-5.05
Vickers Hardness	500-1130
Rupture Modulus (1000 psi)	
70 °F	22-30
1600 °F	30-40
2300 °F	40-78
2500 °F	37-65
2750 °F	22-36
Young's Modulus (1,000,000 psi)	
70 °F	43-47
1600 °F	about 40
2500 °F	20-25
Compressive Strength (1000 psi)	
70 °F	150-200
1600 °F	130-190
2500 °F	70-80
Oxidation Resistance (mils penetration in 100 hr)	
2500 °F	0.3-0.9
2700 °F	0.9-2.0
Specific Heat (Btu/lb-deg F)	
1000 °F	0.22-0.39
2700 °F	0.26-0.47



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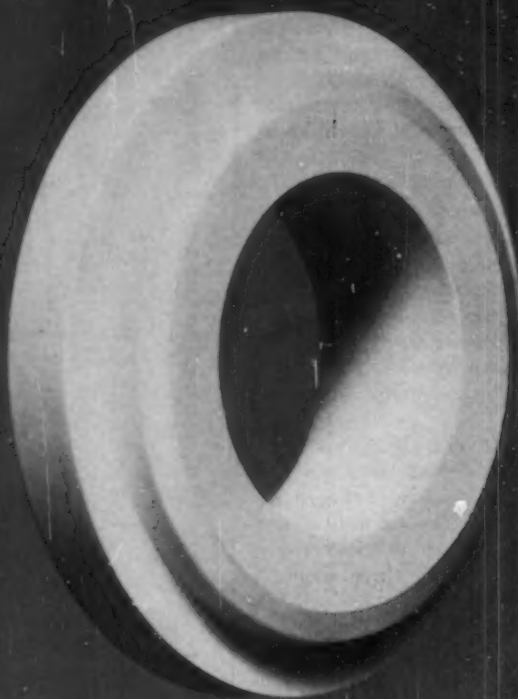
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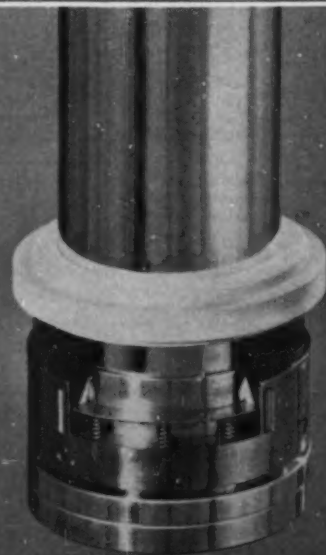
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Circle 212 on Page 19



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HELPFUL LITERATURE

Descriptions of items start on Page 186.
Starred items are from Nov. 9 issue.

Electrical, Electronic

- 501 Motor Relays. 24 pp. Assembly Products Inc.
- 503 Precision Resistors. 16 pp. California Resistor Corp.
- 507 Tachometer Systems. 12 pp. Herman H. Sticht Co. Inc.
- 515 Power Metal Film Resistors. 2 pp. International Resistance Co.
- 518 Snap-Action Switches. 20 pp. Cherry Electrical Products Corp.
- 522 DC Solenoids. 4 pp. Synchro-Start Products Inc.
- 524 Electric Motors. 26 pp. Elcar Div., Indiana General Corp.
- 528 Gear Motors. 6 pp. Electro Counter & Motor Co.
- 530 Power Foot Switches. 8 pp. Linemaster Switch Corp.
- 531 Circuit Breaker. 4 pp. Standard Control Div., Westinghouse Electric Corp.
- 602 Rotary Electrical Equipment.* Describes miniature motors, gyroscopes, servos, blowers, synchros. 4 pp. Siemon Mfg. Co.
- 603 Integral-Horsepower Motors.* Applications for four-cycle, 4 to 24-hp units. Form EN403, 12 pp. Kohler Co.
- 604 High-Temperature Wires.* Various types of wire, tubing, cables, and tape. 58 pp. Hitemp Wires Co., Div., Simplex Wire & Cable Co.
- 605 Foot Switches.* Covers five cast-iron units in 14 forms. Bulletin GEA-7086A, 4 pp. General Electric Co.
- 606 Electronic Components.* Covers various types of plugs, jacks, posts, clips, terminal blocks. 6 pp. National Tel-Tronics Corp.
- 607 Multipoint Gages.* Indicate draft, pressure, differential, and temperature. Bulletin 322.11, 4 pp. Republic Flow Meters Co.
- 608 Optical Terminology.* First in a series of terminology glossaries. "Glossary of Optical Terminology," 1 p. Servo Corp. of America.
- 609 Impulse Transmitters.* Five basic Sodeco units and variations described. 4 pp. Landis & Gyr Inc.
- 610 Synchronous Motors.* Covers bifilar and four-leaded Sta-Syn units. Form SE-L 36161, 4 pp. Superior Electric Co.
- 611 Power Control Units.* Are rated 1 to 15 kva. Bulletin 4-61, 8 pp. Magnetics Inc.
- 612 Cooline, Retention Devices.* Covers tube clamps, retainers, shield inserts, transistor retaining clips, heat radiators. Catalog 1W, 8 pp. Industrial Div., Birtcher Corp.
- 613 Tiny Switch.* Bi-Reed unit is 0.75 in. long. Sheet BR-1, 2 pp. RBM Controls Div., Essex Wire Corp.
- 614 Capacitors and Resistors.* Quick-reference data on capacitors, resistors, plate assemblies, filters. Catalog IDC-561, 56 pp. Aerovox Corp.
- 615 Electronic Cabinet.* Gives data on Unicabinet electronic rack cabinet. Folder U101, 6 pp. Dahlstrom Mfg. Corp.
- 616 Zener Diodes.* Two bulletins cover 1 and 10-w units. Bulletin 6.353, 6.354, 4 pp. Farnsteel Metallurgical Corp.
- 617 Push-Pull Cable.* Design requirements for various applications. Form 162, 4 pp. Push Pull Cable Div., Morse Instrument Co.
- 618 Timing Instruments.* Covers over 100 different units. 16 pp. Heuer Timer Corp.
- 619 Miniature Delay Lines.* Wee Line sectionalized

delay lines covered. Form S-53, 4 pp. Nytronics Inc.

Hydraulic, Pneumatic

- 502 Industrial Gas Data. 48 pp. Air Reduction Sales Co., Div., Air Reduction Co. Inc.
- 508 Air Cylinder. 48 pp. Tomkins-Johnson Co.
- 512 Vane Pumps. Denison Engineering Div., American Brake Shoe Co.
- 521 Hydraulic Valve. 12 pp. Cash-Acme.
- 523 Hydraulic Filter. 4 pp. Vickers Inc., Div., Sperry Rand Corp.
- 527 Hydraulic Equipment. 8 pp. Star Hydraulic Inc.
- 529 Blowers and Pumps. 8 pp. Roots-Connorsville Blower Div., Dresser Industries Inc.
- 620 Valves and Cylinders.* Describes popular models in standard line. 4 pp. Rivett Lathe & Grinder Inc.
- 621 Glass Pump.* Covers Goulds-Pfaudler 1-in. pump. Bulletin 725.3, 4 pp. Goulds Pumps Inc.
- 622 Bypass Rotameters.* Shows how measurement and control of flow rates are accomplished. Bulletin 116, 8 pp. Brooks Instrument Co. Inc.
- 623 Hydraulic Power Packages.* Contain pump, electric motor, valve, and reservoir. Bulletin 61-82, 4 pp. Vickers Inc., Div., Sperry Rand Corp.
- 624 AC Pump Motors.* Covers two groups of motors for pump-duty service. Bulletin L-4121A, 6 pp. Kingston-Conley Inc.
- 625 High-Temperature Seal.* For fluid systems with up to 10,000 psi pressure. Bulletin E15, 2 pp. Peli Corp.
- 626 Pumps and Components.* In capacities to 100 gpm, pressures to 3000 psi. Bulletin 47740, 20 pp. Oilgear Co.
- 627 Dry Lubricant.* Applications of Molykote G, grease-type lubricant. Bulletin 131, 2 pp. Alpha-Molykote Corp.
- 628 Valve Sizing.* Explains undersized, over-sized, and correctly sized pressure-reduction apparatus. Jordan Valve Div., Richards Industries Inc.
- 629 Gate Valves.* King-Clip units withstand severe corrosive action. Circular 561, 4 pp. Lunkenheimer Co.
- 630 RFI Gasket.* Describes Tackstik quick-installation unit. Data Sheet RF-15, 2 pp. Technel Wire Products Inc., 129 Dermody St.

Mechanical Equipment

- 504 Self-Lubricated Bearings. 8 pp. Bronze Bearings Inc.
- 509 Spur-Gear Racks. 8 pp. PIC Corp.
- 513 Thin-Section Bearings. 2 pp. Industrial Technics Inc.
- 516 Universal Joints. 6 pp. Hydraulic Div., Twin Disc Clutch Co.
- 631 High-Temperature Bearings.* Describes Haynes Alloy 25 corrosion-resistant bearings. Tech-Tonic 11, 3 pp. Industrial Technics Inc.
- 632 Variable-Power Drive.* Torque-rated Vari-Power units described. Catalog 761, 8 pp. Ferguson Machine Co., Div., Universal Match Corp.

DESIGN

- 633 Cams and Camshafts.* With tolerance of ± 0.00001 in. Bulletin 210, 6 pp. Eonic Inc.
- 634 Lubricated Bearings.* Covers Life-Lube bearings, pillow blocks. Bulletin 7104, 12 pp. T. B. Wood's Sons Co.
- 635 Light-Duty Conveyor Chains.* Rex Table-Top and Plate-Top units of various materials. Bulletin 6158, 40 pp. Chain Belt Co.
- 636 Laster Bases.* Covers three series of automatic units. 8 pp. Mannheim Mfg. & Belling Co.
- 637 Solenoid-Operated Brakes.* Type S units for use where small brakes are required. Publication LJ-75, 4 pp. Cutler-Hammer Inc.

Assembly Components

- 638 Extension Springs. 2 pp. Hunter Spring Co., Div., American Machine & Metals Inc.
- 638 Self-Sealing Fasteners.* Sealstrips, Sealbolts, Sealrivets, Kapt-Oskrows. Catalog H61, 4 pp. A. P. M. Corp.
- 639 Instrument Counters.* Covers mechanical and electrical units and applications. Catalog 400, 16 pp. Durant Mfg. Co.
- 640 Standard Lock Bolts.* Covers operation, application, and installation. Bulletin T-194, 8 pp. Engineered Fasteners Div., Townsend Co.

Manufacturing Processes, Parts

- 641 High-Alloy Castings.* In static, centrifugal, and shell-molded types. 20 pp. Duraloy Co.
- 642 Welding Symbols Chart.* Data on basic weld symbols and location significance. Lenco Inc.

Materials

- 505 Friction Materials. 24 pp. Packing & Friction Materials Div., Johns-Manville Corp.
- 510 Laminated Plastics. 8 pp. Taylor Fibre Co.
- 514 Nonferrous Castings Alloys. 4 pp. Wisconsin Centrifugal Foundry.
- 519 Reinforced Plastics Parts. 4 pp. Biscioff Chemical Corp.
- 643 Fluorosilicone Data.* Three bulletins cover fluids, greases, and compounds. Bulletins 15-200, 15-201, 15-202, 8 pp. Dow Corning Corp.
- 644 Nylon Shapes.* Physical properties of Cadco nylon shapes. 8 pp. Cadillac Plastic & Chemical Co.
- 645 Reinforced Plastic.* Properties of Tylonar PA reinforced plastic. Bulletin 8.5, 2 pp. Taylor Fibre Co.
- 646 Acrylic Molding Powder. Covers Implex-R high-impact plastic molding powder. Bulletin PL-476, 4 pp. Rohm & Haas Co.

Engineering Dept. Equipment

- 506 Interlocking Tube Files. 28 pp. Pack Mfg. Co.
- 511 Recorders. 12 pp. General Electric Co.
- 517 Precision Test Instruments. 24 pp. B & K Instruments Inc.
- 520 Self-Contained Recorder. 4 pp. Impact-O-Graph Corp.
- 526 Monitoring System. 4 pp. Nuclear Measurements Corp.
- 647 Portable Tensile Testers.* Covers models TT and TJ units. Bulletin 750/P, 4 pp. Hunter Spring Co.
- 648 Weldable Strain Gages.* SR-4 units for temperatures from cryogenic to 750 F. Data Sheet 4324, 2 pp. Electronics & Instrumentation Div., Baldwin-Lima-Hamilton Corp.
- 649 Data-Acquisition System.* MicroSADIC high-speed, solid-state system. Bulletin 3047, 16 pp. Consolidated Systems Corp.
- 650 Data-Recording System.* Records 14 tracks of data with precision. Brochure 3.11, 4 pp. Westrex Co., Div., Litton Systems Inc.
- 651 Humidity Meter.* Humidi-Meter unit permits instant measurement of relative humidity. Form HI 25-961, 2 pp. Telostat Corp.
- 652 Tape Recorder-Reproducer.* FR-100 C magnetic unit is described. 4 pp. Ampex Corp.

Electrical, Electronic

- 533 Silver-cadmium button cells in six capacities from 0.25 to 6 amp-hr. Yardney Electric Corp.
- 535 Semiconductor networks in six different digital-circuit modules. Texas Instruments Inc.
- 540 Electrolytic potentiometers for units needing tilt indication. Hamlin Inc.
- 543 Silicon-controlled rectifiers in eight models are highly sensitive. Rectifier Components Dept., General Electric Co.
- 547 Neon indicator lights are subminiature, transistorized units. Dialight Corp.
- 549 Flexible terminal block can be bent to fit contours, sharp angles. National Tel-Tronics Corp.
- 554 Wiring raceway has open-end wire slots. Stahlin Brothers Inc.
- 556 Appliance switch needs only 1/2 in. mounting clearance. Electronic Components Div., Stackpole Carbon Co.
- 557 Miniature meters have watt input as low as 1.5 w. Martronics Inc.
- 561 Variable transformer is rated at 10 amp and 1.4 kva. Standard Electrical Products Co.
- 565 Split-phase motors for belt-drive blowers and fans. Industrial Motor Dept., Westinghouse Electric Corp.
- 567 Adjustable-step switches are extremely flexible in use. Daven Co.
- 569 Synchronous motor has output speeds of 300, 600, or 1200 rpm. Beav Electronics Inc.
- 581 Pneumatic timer has time range of 0.2 to 15 sec. Hagen Mfg. Co.
- 584 Footless gear motor from 1 to 5 hp, 230 to 780 rpm. U. S. Electrical Motors Inc.
- 585 Vitreous-enamelled resistors in values from 1 to 6000 ohms. Ohmite Mfg. Co.
- 588 Low-pressure indicator for range of 0 to 40 in. water. Aero Mechanism Inc.
- 589 Single-turn potentiometer has diameter of 5/16 in. Trimpot Div., Bourns Inc.
- 592 Speed control for U. S. Variable motors. U. S. Electrical Motors Inc.
- 593 Pressure switch for temperatures from -65 to +250 F. Haydon Switch Inc.

Hydraulic, Pneumatic

- 536 Metallic static seals for all standard AN cavities. Servotronics Inc.
- 541 Vane-axial blower for 400-cycle power is 2-in. unit. Globe Industries Inc.
- 545 Sealing device provides seal to 3000 psi with no spiral failure. W. S. Shamban & Co.
- 580 Hose clamp for use where hose or fitting is subjected to abrasion. Cuyahoga Products Corp.

- 553 Check valve provides full closure or slow, calibrated leak. Chemquip Co.
- 558 Nonclogging nozzles for one-piece construction. Beto Fog Nozzle Inc.
- 560 Rotary actuators are miniature units with low power consumptions. Nash Controls Inc.
- 562 Packing lubricants for temperatures to 500 F. Garlock Inc.
- 564 Variable-displacement pumps deliver 5 to 108 gpm at 1100 to 3000 psi. Oilgear Co.
- 568 Lubrication system of anodized aluminum. Air-matic Valve Inc.
- 570 Pressure indicators for system working pressures to 10,000 psi. Pall Corp.
- 572 Hydraulic line filter has built-in condition indicator. Gresen Mfg. Co.
- 576 Air-control valve has large flow capacity. Han-nifin Co.
- 580 Solenoid-operated valve for temperatures from 40 to 175 F. Ross Operating Valve Co.
- 582 Tube joint for 150-lb service. Marman Div., Aeroquip Corp.
- 586 Soft packing for solvent and mild acid or mild alkali service. Garlock Inc.
- 591 Hydraulic cylinders with bores from 1 1/2 to 14 in. Denison Engineering Div., American Brake Shoe Co.

Mechanical Equipment

- 532 Oldham couplings have backlash tolerance of 8 min. of arc. Dynamic Gear Co. Inc.
- 537 Reversing transmissions in size from 2 to 75 hp. Turner Uni Drive Co.
- 542 Adjustable motor bases for use on belt drives to 1 hp. Rampe Mfg. Co.
- 548 Overload protector coupling runs in disengaged position without heat or binding. Holland Research & Engineering Inc.
- 582 Slip couplings are designed for continuous slip. Machine Components Corp.
- 563 Flexible-shaft coupling with maximum torque capacity of 470 lb-in. Stow Mfg. Co.
- 571 Index locking device adjusts control linkage and cylinder rod ends. Arwood Corp.
- 573 External vibrators are available in three sizes. Tremix Co. Inc.
- 577 Mechanical limit stops for 0-10 and 0-40 turns. Northfield Precision Instrument Corp.

Assembly Components

- 534 One-piece lock nut in sizes from No. 10 to 1/2 in. Lokan Locknut Div., Allen Mfg. Co.
- 539 Prevaling-torque lock nut allows uniform torque control. Automatic Products Co.

- 546 Mechanical counters for digital-readout applications. Veeder-Root Inc.
- 555 Tab weld nuts of low-carbon steel in two new types. Grip Nut Co.
- 559 Plastic-covered handles in 1 1/4, 2, and 3-in. widths between centers. Cambridge Thermionic Corp.
- 566 Lock washers in sizes from No. 10 to 1/2 in. Shakeproof Div., Illinois Tool Works Inc.
- 574 Reversible counter has nylon drums and pinions. Haydon Instrument Co.
- 579 Explosive-actuated nuts accommodate bolt thread sizes from 1/4 to 1 1/2 in. Conax Corp.
- 583 Stressed panel fastener is smaller than NAS 547 Size O. Deutsch Fastener Corp.
- 587 Precision component hangers accommodate various sizes of ball bearings. Sterling Instrument Div., Designatronics Inc.

Materials

- 538 One-component adhesive for temperatures from -70 to +200 F. Adhesives, Coatings, and Sealers Div., Minnesota Mining & Mfg. Co.
- 544 Polyurethane molding material can be cured in 3 min. Naugatuck Chemical Div., United States Rubber Co.
- 551 Flocking adhesive is flame-resistant. Allen Plastics Corp.
- 573 Two-part adhesive for high-temperature applications. Emerson & Cuming Inc.
- 578 Gasket sheeting of rubber and asbestos. Rogers Corp.
- 590 Injection-molding material in a variety of colors. Eastman Chemical Products Inc.

Engineering Dept. Equipment

- 594 Air-volume computer gives free-air volume for cylinders of any bore, stroke. Flow Finder.
- 595 X-Y recorder has accuracy of ± 0.1 per cent of full scale. F. L. Moseley Co.
- 596 Spaced lettering for pressure-sensitive layouts. Chart-Pak Inc.
- 597 Copying machine makes permanent copies 9 in. wide by any length. Photostat Corp.
- 598 Laboratory controller is a true proportional controller, free of cycling. Brooks Instrument Co.
- 599 Solid-state voltmeter achieves average of 200 readings per sec. Electronic Associates Inc.
- 600 Linear accelerometer has weight of 4.5 grams. Statham Instruments Inc.
- 601 Volt-ohm meter covers frequency spectrum from 20 cps to 700 mc. Borg-Warner Controls, Div., Borg-Warner Corp.

EDITORIAL ARTICLES

Single copies of the following articles are available as long as the supply lasts. Starred items are from previous issues. See Page 249 for other available reprints. Editorial content of *MACHINE DESIGN* is indexed in the Applied Science Technology Index and the Engineering Index, both available in libraries. Microfilm copies are available from University Microfilms, 313 N. First St., Ann Arbor, Mich.

- 24-1 B-70 Hydraulics. All previous MIL-Spec standards have been discarded in large, complex system. (4 pp.)
- 24-2 Why New Products Fail. Common reasons for failure; how to avoid product-planning pitfalls. (4 pp.)
- 24-3 Tolerance Standards. Minimizing notes on engineering drawings by setting up company tolerance standards. (5 pp.)
- 24-4 Space Mechanisms. Finding velocities and accelerations of 3D mechanisms by fundamental graphical methods. (4 pp.)

- 24-5 Neutral Axis of an Unsymmetrical Beam. Quick, accurate method for determining the neutral axis of an unsymmetrical section. (1 p.)
- 24-6 Designing Bevel Gears. New method based on preventing bevel-gear failure caused by pitting. (7 pp.)
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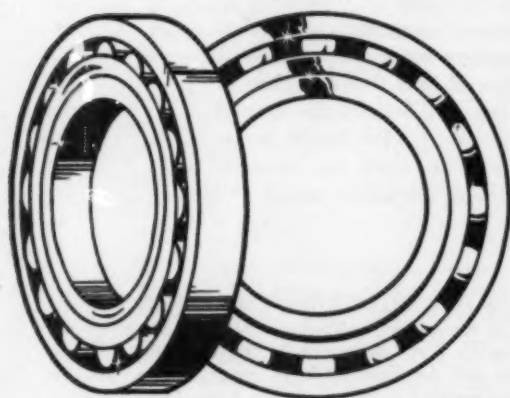
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engineering/personal

AIEE and IRE May Merge

Consolidation is being considered by the two largest engineering societies in the world, the American Institute of Electrical Engineers and the Institute of Radio Engineers. The new organization would be an international one in which the 91,000 members of IRE and the 70,000 members of AIEE would enjoy the same rights and privileges afforded by their present membership. Officers and former officers of both societies have been appointed to a committee which is studying the consolidation. They will report to their boards of directors by next February. A vote of members and consummation of the merger, if approved, is anticipated by January 1, 1963.

THE NEED FOR ENGINEERS rose during September, according to the latest Engineer/Scientist Demand Index compiled by Deutsch & Shea Inc., New York. The September figure, 116.7, showed a 3.5 per cent increase over the previous month and was the highest since the index was begun 15 months ago. Figures are based on newspaper classified and display advertising and technical-journal advertising. The figure for August was 112.8 and for September, 1960, 104.2 (July-Dec. 1960 = 100).

ENGINEERS IN R & D WORK increased 51 per cent in four years, according to a National Science Foundation report. This gain is almost double that for scientists and engineers in other activities. In 1958, 208,000 engineers were engaged in all phases of research and development, compared to 138,600 in 1954. The total figure breaks down to 177,700 employed by industry, 20,800 by the federal government, 8000 by colleges and universities, and 1500 by other nonprofit institutions.

research

Walk-In Chamber Is Optimum for Ozone Tests

The world's largest prefabricated ozone test chamber (8 x 9 x 8 ft) will be used by the Army Ordnance Tank-Automotive Command to test tires (up to the size that fits earth-moving equipment) and other rubber and polyethylene materials. Atmosphere inside the chamber is automatically controlled to provide a mixture of from 0 to 500 parts of ozone per 100 million parts of air (as much as 5.5 times the normal amount). Temperature range is -65 to 150 F. Previously, ozone testing at OTAC was done on swatches in an oven-size chamber and results were projected—often incorrectly—to the whole part.

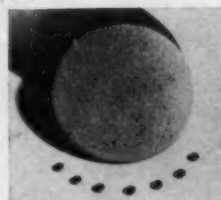


SIXTEEN BILLION DOLLARS will be spent for research in 1962. This is the prediction of George W. James, economist at Battelle Memorial Institute. Dr. James estimates that the government will spend about \$10 billion; industry, about \$5.5 billion; and universities and foundations, about \$350 million. In 1950, research spending totalled only \$3 billion; last year it amounted to \$14 billion. "If research were considered an industry," says Dr. James, "its total 'sales' would rank it about midway among the 20 major manufacturing industries in the United States."

A NEW METHOD OF POWER CONVERSION will be studied by Westinghouse Electric Corp. for the Air Force. Subject of the research is the Austin cell, developed by B. O. Austin, a consultant engineer at Westinghouse's Lima, Ohio, plant. Mr. Austin discovered that certain metals, separated by a porcelain enamel, produce electric power when heated. Inserting thin plates in a toaster produced enough power to drive a small electric motor and its propeller. Austin cells may work at temperatures too high for conventional power sources—in rocket nozzles, for instance.

Slicing Slugs for Semiconductors

Extremely flat tungsten discs up to 1 in. diam are made by a new slicing and lapping technique developed by the Electrical Contacts and Specialties Div., Fansteel Metallurgical Corp., North Chicago, Ill. Discs as small as 0.060 in. diam and as thin as 0.020 in. are possible. Flatness is within 0.0001 in. Besides large size and flatness, Fansteel lists four other advantages of the new process: The discs are highly uniform and dense because they are cut from wrought rods instead of rolled sheets; they have square edges; cracking in layers does not occur; and they cost less than punched discs because slicing causes less waste.

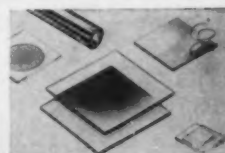


DIE-STAMPED CIRCUITS, produced at a high rate and therefore low cost, are uniform and perform reliably. Circuits supplied by Dytronics Inc., Rochester, Mich., are made by die-cutting the conductor pattern from metal foil coated on one side with a thermoresponsive adhesive; simultaneously, the circuit is bonded to the insulating base material by heat and pressure.

SOLDERING ALUMINUM to stainless steel without using a flux eliminates the possibility of destruction of the joint by electrolytic action caused by occlusion of the flux. A flux-free method of joining the two metals has been developed by Hanford Atomic Products for the Atomic Energy Commission. The stainless is tinned with 50 per cent lead and 50 per cent tin solder; the aluminum is tinned with aluminum solder containing 97.88 per cent tin and small amounts of aluminum, copper, iron, lead, and silicon. The two surfaces are placed in contact and heated to 500-600 F to form a gastight joint.

ONE-PIECE WELDED RETAINERS last longer than riveted or other types, according to the Fafnir Bearing Co., New Britain, Conn. Fafnir reports that its new process for welding ball-bearing retainers has increased life of cages for rugged applications from 200 to 450 per cent. In pull-apart load tests, the welded retainer showed 1.73 times the strength of a riveted design.

VACUUM-DEPOSITED FILMS a few millionths of an inch thick, controlled to within ± 5 per cent, can be applied to plastic, metal, glass, and ceramic by a process developed by Evaporated Coatings Inc., Huntington Valley, Pa. The development permits deposition of low-vapor-pressure materials not formerly available on surfaces which up to now have not been vacuum-coated. The new process uses an electronic monitoring system which can measure as little as 100 angstroms. The thin films are compatible with organic substrates.



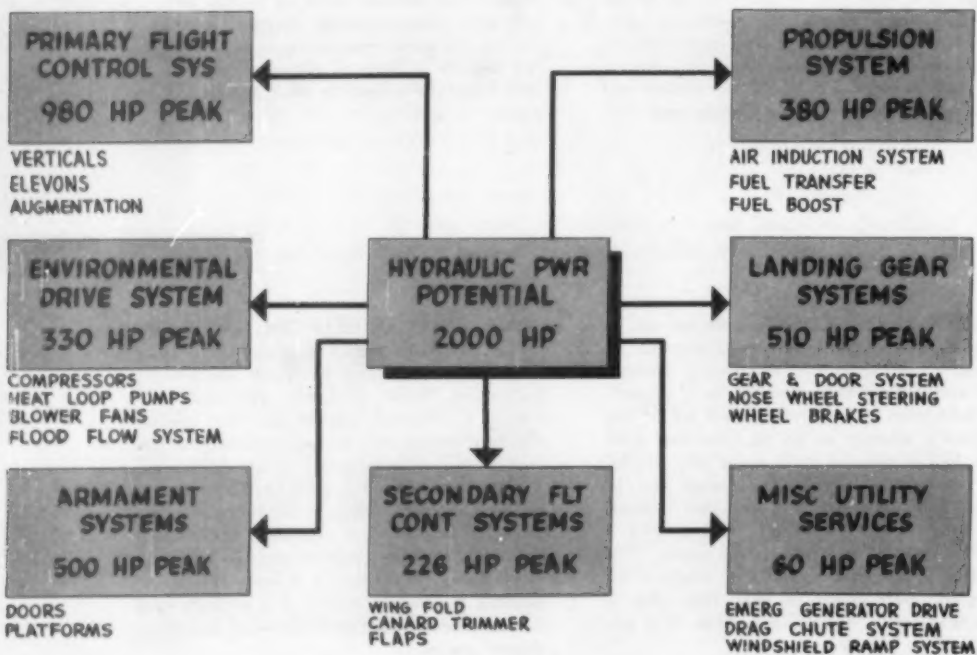
WHOLESALE HOMEWORK is turned out by an IBM 709 computer at the University of Michigan. Used mainly by engineering students, it is available to those enrolled in 97 courses. All sophomores in engineering solve one or two problems a semester on the computer and work up to four or more in their senior year. Studies have shown that engineering students can be taught more extensive and complex material when they use a computer. Starting with a machine designed and built at the school, U-M has had a computer available to students for ten years. Next spring an IBM 7090, able to solve the average homework problem in 4 seconds, will be installed.

COMPUTERS CAN HELP DOCTORS by providing rapid and precise diagnoses. In a paper presented at the recent Computer Applications Symposium, Robert S. Ledley said that it is possible to efficiently convert the entire medical diagnostic process into mathematical models. The models can then be programmed into a computer. A doctor must spend a good deal of time analyzing a patient's symptoms and formulating his plans for treatment. A computer, according to Dr. Ledley, provides a quicker analysis of all steps in diagnosis. In addition, it is more accurate in recalling the desired aspects of a patient's total medical record, including biochemical and physiological norms.

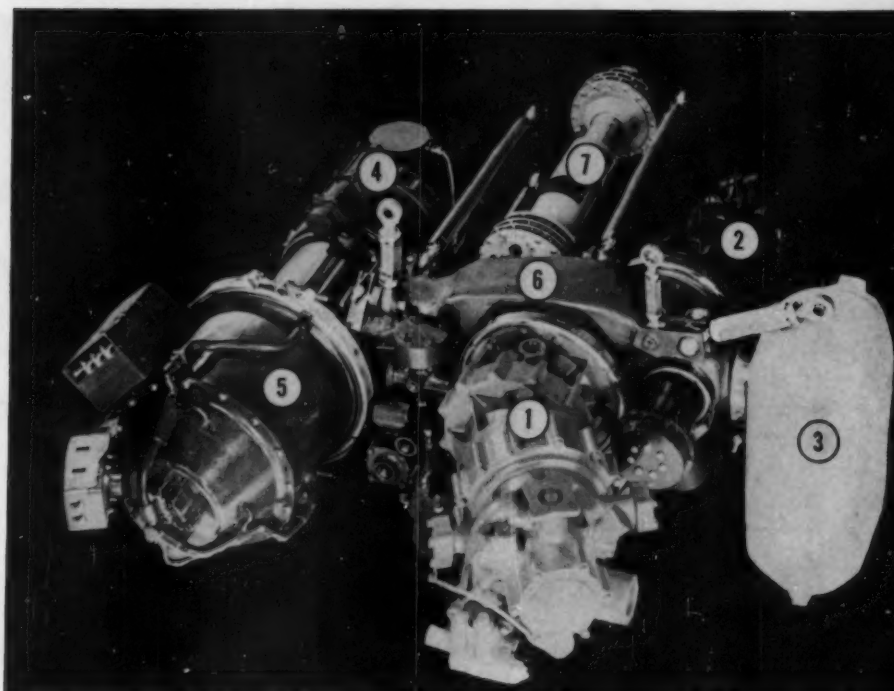
B-70 Hydraulics: High Powered

**News
Report**

Fluid power—2000 hp worth—is the prime source of secondary power on the forthcoming B-70 bomber. Because of severe environmental and operational rigors imposed by Mach-3 flight, the Air Force authorized North American Aviation to abandon MIL hydraulic specs and improvise freely in design of B-70 hardware and systems.



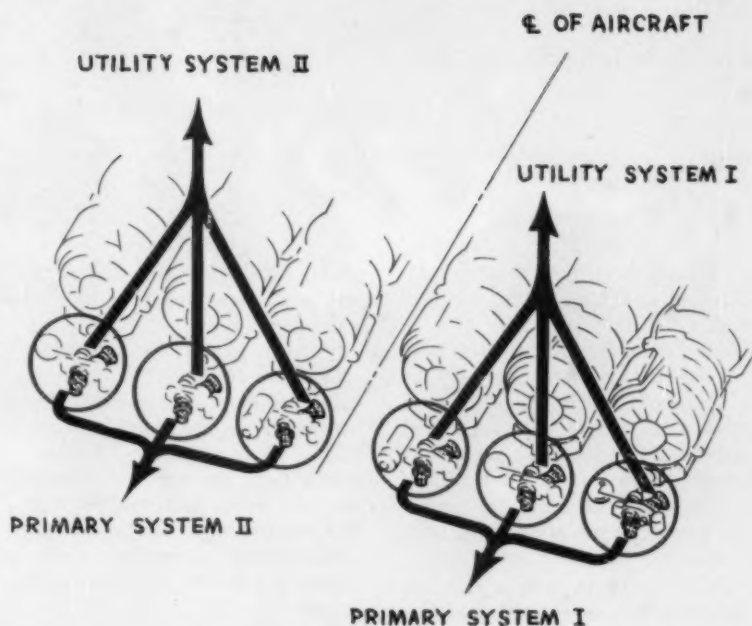
and Hot



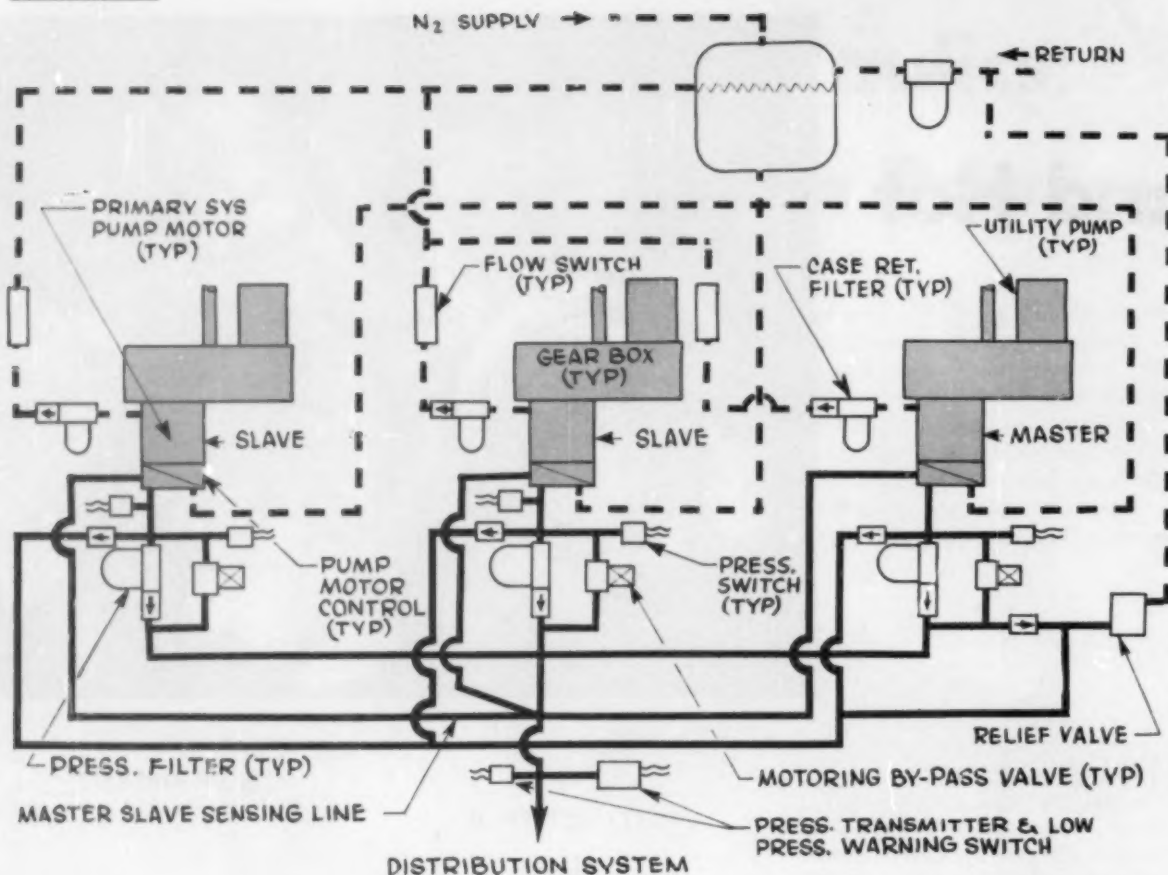
IN addition to all of its other superlative characteristics—size, speed, range, payload—the B-70 bomber will carry more fluid-power equipment than any other aircraft ever built. Four independent hydraulic systems will power seven of the aircraft's basic subsystems.

B-70's impressive roster of hydraulic hardware includes 85 linear actuators, 44 rotary actuators, or motors, 120 solenoid-operated valves, and 50 mechanically activated valves. The aircraft will be lined with more than one mile of hydraulic tubing, requiring approximately 3300 brazed connections and 600 mechanical joints. Each of the four hydraulic systems (two primary, two utility) will be powered by three positive-displacement, variable-output pumps driven by the aircraft's huge jet engines. Fluid capacity of the four systems totals 220 gal at room temperature, increasing to 260 gal at 450 F. Hydraulic pressure will be maintained at about 4000 psi.

In addition to the sheer quantity of equipment used, size and capacity of individual components is also impressive. Output of some of the large tandem actuators exceeds 316,000 lb; they weigh more than 290 lb. Diameters of actuator-piston bores range from 1 to 7.25 in.;



Six secondary power packages, one per jet engine (sketch), activate four independent hydraulic systems on the B-70. Individual power package (photo, top) consists of: 1. Primary-system pump. 2. Utility-system pump. 3. Alternator-drive reservoir. 4. Constant-speed drive. 5. Alternator. 6. Gearbox. 7. Driveshaft. Alternators are mounted on two inboard engines only; dual-system reliability—electrical and hydraulic—is based on 3 x 3 jet-engine hook-up.



Master-slave pump arrangement in primary and utility systems reduces heat, increases reliability of the B-70 system.

strokes vary from a few inches to a maximum of 30 in., with extended lengths of 6 ft.

Bulk oil temperature in the system will be maintained at 450 F; maximum pump-inlet temperature at 400 F. Hot spots in the system will reach 630 F, with non-continuous flowing systems in the 530-F region. At the other extreme, the entire fluid-power layout must be capable of operation at -65 F.

Fuel is used as a heat sink for the hydraulic system. Oil reservoirs are completely submerged in the integral aircraft fuel cells. Reservoir pressurization and inerting is accomplished with dry nitrogen.

Slaves Beat the Heat

Size of the B-70 hydraulic system, plus the expected environmental conditions and duty-cycle requirements, posed an obvious problem in hydraulic heating. The total available fuel for cooling was not ade-

quate to handle the 25,000 Btu per min generated by hydraulic equipment.

Since the pumps alone contributed approximately 15,000 Btu per min, their position in the scheme of things became an area of design concentration. NAA engineers devised a master-slave concept which reduces the total pump heat-rejection to 10,000 Btu per min. It also minimizes engine-power extraction, and increases the service life of two pumps in each system.

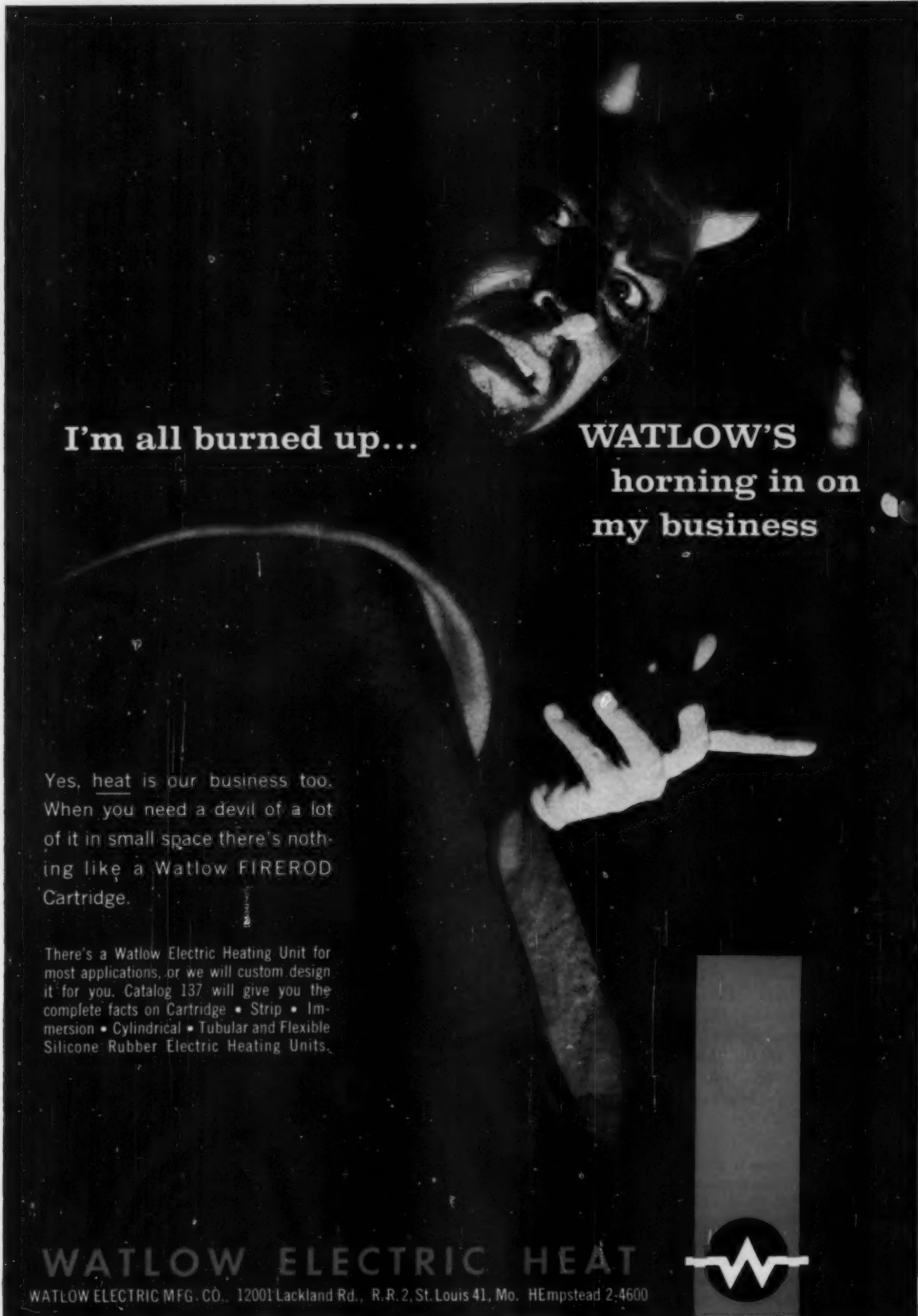
In the NAA concept, master pump in each of the three-pump systems supplies continuous demands; the other pumps, called slaves, remain positioned to a minimum power output. Depressurized to approximately 250 psi, they pump only enough oil for their own lubrication and cooling. Slave pumps are sequenced on the bus as the demand requires. In case of a master-pump failure, the first slave becomes the master, and

the system functions in a normal manner, although at a lower potential output.

Each primary-system pump, in addition, operates as a constant-hp motor for engine starting. Internal valving within the pump permits its operation as a motor by pressurization of the pump outlet port, rotating the unit in the pumping direction. Use of pumps as engine start motors eliminated 380 lb of additional engine-starting equipment.

Materials: Seals Are Critical

Vacuum Melt H-11 heat treated to 260-280,000 psi is used almost exclusively in all actuators for cylinder barrels, pistons, piston rods, end caps, and rod ends. Inside surfaces in contact with oil are left bare with external surfaces coated with Coroloy (zinc nickel coating). Piston rods are Linde LW-1 tungsten carbide flame plated and



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lapped.

Two types of self-aligning bearings are used. Actuators in areas of below 530 F utilize fibroid liner coated bearings; actuators in areas above 530 F use dry-film lubricant. Bearing pressures are designed to a nominal 30,000 psi.

Probably the largest development program now in progress is the design and development of all types of seals to replace the usual elastomer "O" rings. Seven basic seals are required for equipment items: Static face, two types of static diametral seals, dynamic piston rings, oscillatory, and first and second-stage dynamic rod seals. Metallic seals, fabricated by North American, are currently being used successfully, although they are still largely in the developmental stage.

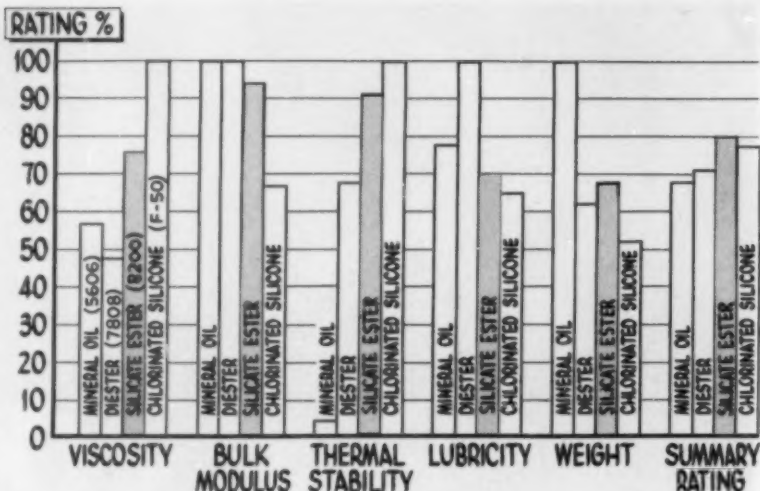
Actuator-cylinder barrels are designed to burst requirements only. Deflection under pressure or maintaining a specific maximum clearance between piston and cylinder bore to take care of extrusion problems no longer exists, since the metal piston rings are structurally capable of operating under increased piston-to-bore clearances. This has permitted considerable weight saving in the design of all large actuators.

Suppliers Share Secrets

The weapon-system concept used in building the B-70 has established some supplier relationships which normally would never be consummated. The relationships have required disclosure in proprietary state of the art and complete co-operation between suppliers of similar equipment.

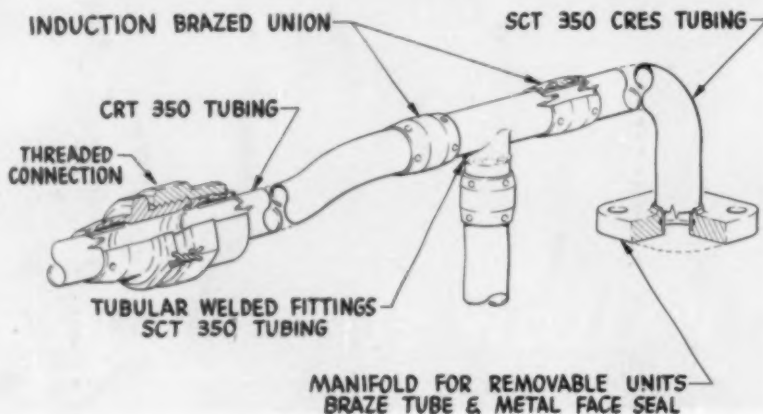
The procurement of complete subsystems has allowed industry to contribute the best talent for a specific job. However, the responsibility of the weapon system contractor, as well as the Air Force, in surveillance over major subsystems has required a large effort.

This article is based on a description of the B-70 fluid-power systems, presented by R. J. Dawson, engineering group leader, Fluid Power Systems, North American Aviation Inc., at the recent Aerospace Fluid Power Conference, sponsored by Vickers Inc., Detroit.



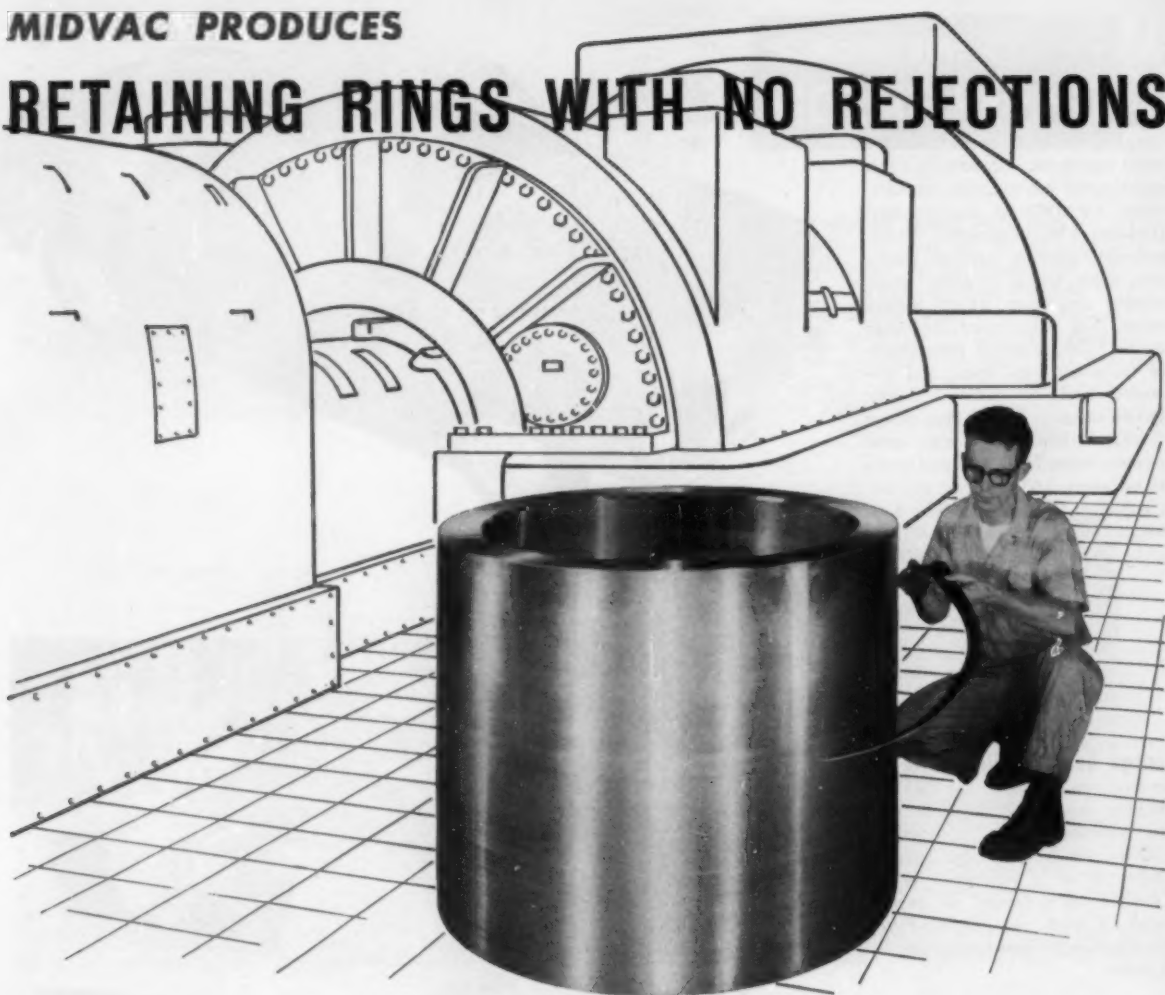
Although a nonflammable fluid would be highly desirable for the B-70, none with this characteristic is capable of operating over the required temperature range. Five properties were considered in fluid evaluation program: 1. Viscosity. 2. Bulk modulus. 3. Thermal stability. 4. Lubricity. 5. Weight. The most promising fluids fell into four "families" as far as chemical composition was concerned: 1. Mineral oils. 2. Diesters. 3. Silicate esters. 4. Chlorinated silicones. The best representative fluids from each "family" were considered under a program of comparative evaluation. The fluid or fluid family which had the best characteristics in relation to each major property was given a rating of 100 per cent in that property, with the other fluids rated equal or lower in comparison. A summary rating, which averaged the five major property ratings, indicated that the silicate ester family of fluids has the best balance of characteristics required. Oronite 8200 fluid was thus selected for use in the B-70.

CRT (cold reduced and tempered) tubing is used for general line plumbing in the B-70. The tubing is work hardened by redrawing to a minimum tensile strength of 185,000 psi. Annealed 350 CRES tubing is used for fittings. Lines and fittings within the airframe are joined with a North American standard brazed union, utilizing silver-lithium copper-braze material. Threaded joints, kept to a minimum, are designed for low installation torque, with no specific torque required—the fitting bottoms positively. A single leak path results which is pressure energized to the sealing position. Fittings are induction brazed to tubing. Where relative motion exists between components and the airframe, and motion is less than 7 deg included angle, coiled tubing is used. Where the required angular change exceeds 7 deg, all-metallic swivel fittings are used. Hoses are not used in any of the B-70 fluid-power systems.



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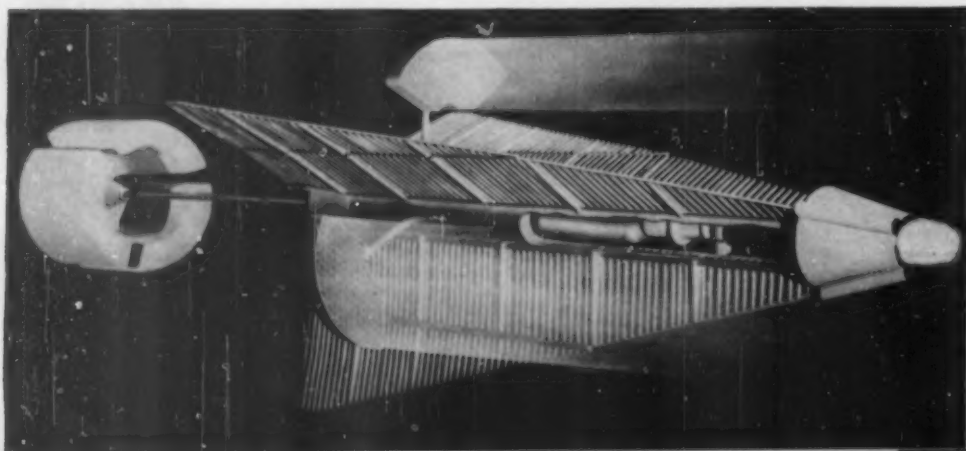
A new body for the Karmann Ghia is the latest news from the Volkswagenwerk. Internally, this sports model has the same improvements for 1962 as the standard (Deluxe) VW. Examples: Worm-and-roller steering (replaces worm-and sector type); modified transmission mounting which reduces noise; fuel gage; more leg room in the front; increased adjustability of front-seat back rests; and improved warm-air outlets. Engine specifications are: Horsepower (SAE), 40 bhp at 3900 rpm; compression ratio, 7.0:1; bore and stroke of cylinders, 3.03 and 2.52 in.; displacement, 72.7 cu in. The Karmann Ghia is 163 in. long, 64.3 in. wide, 52.4 in. high, weighs 1808 lb.



Large bearing surface of a pair of endless tracks keeps the Ski-Doo from sinking into snow as much as a man on snowshoes. Skis in front steer the 335-lb vehicle. A 7-hp Kohler engine drives it at a top speed of 25 mph. Smallest of a family of snow scooters used for work and fun, Ski-Doo is built by Bombardier Snowmobile Ltd., Valcourt, Quebec.



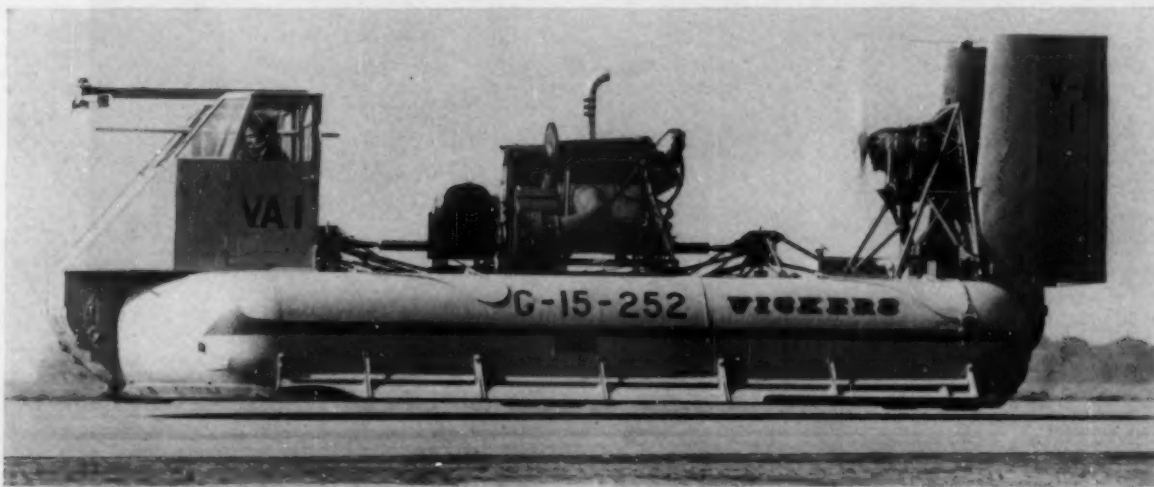
Weighing only 8 lb per kw without shielding, SPUR (Space Power Unit, Reactor) is six times lighter and ten times smaller per kilowatt than previous space power systems. SPUR uses a small atomic reactor to heat and expand liquid metal through a turbine to drive a generator. The turbine-generator package is about 3 ft long, 1 ft in diam, and weighs 350 lb; the whole payload weighs about 1000 lb. AiResearch Phoenix Div., Garrett Corp., is prime contractor and systems manager for the project, undertaken by the Air Force with the co-operation of the Atomic Energy Commission. Prototype ground testing is expected in 1966.





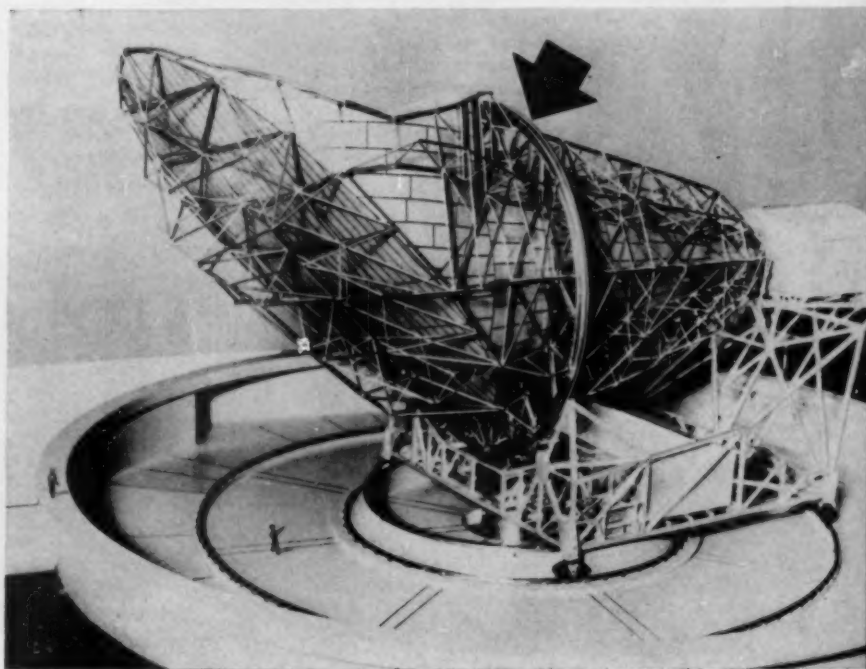
ENGINEERING NEWS PICTURE REPORT

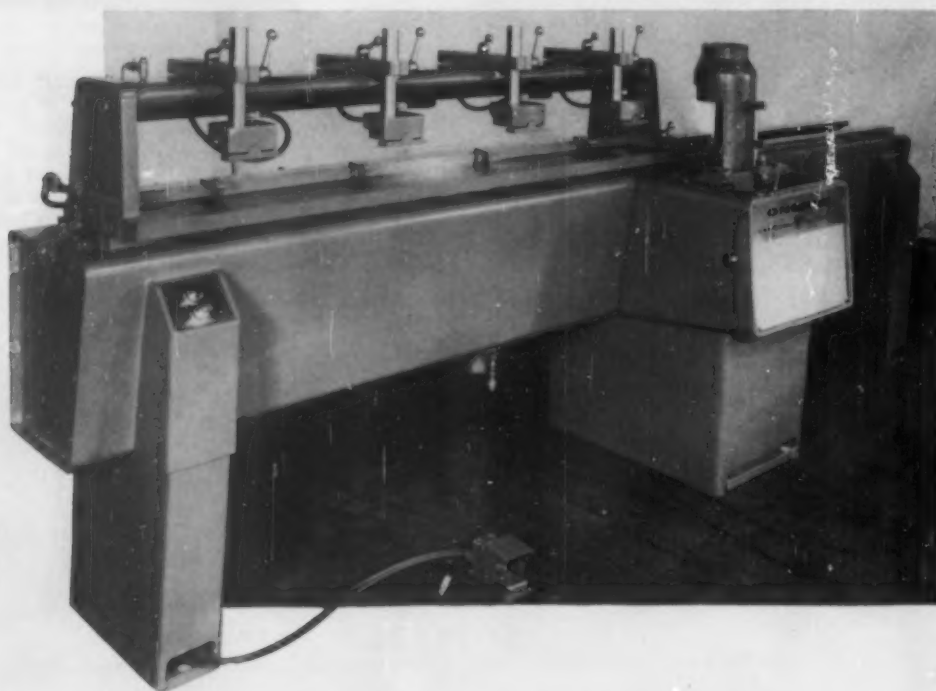
Self-propelled caddy cart runs on a 12-v battery, is good for 18 holes on a charge. Guided by its handle, the cart follows the player, matching his gait. It weighs 79 lb and breaks down to fit into the trunk of a car. A 110-v ac charger and a timer are built into the battery box. Toro Mfg. Corp. makes the Caddy Master; price is \$230.



Air-cushion research is carried on with this vehicle, the VA-1 built by Vickers-Armstrongs Ltd., London. Design features of the VA-1 can be changed to study the effect of variations in jet-nozzle configurations, ducting, and aspect ratio. Other problems that interest Vickers are those created by recirculation of air that has passed through the ducts and the virtues of rectangular vs. circular shapes.

A seven-story high wheel will support the 110-ton antenna horn used for Project Telstar, Bell System's satellite communications experiment. Outer edge of the wheel (indicated by the arrow in this model) consists of a rail which will run in trucks to assure alignment. McKiernan-Terry Corp., Dover, N. J., is erecting the antenna for Bell in Maine.





1.

A machine tool needn't be endowed with the beauty of, say, a television set or a refrigerator, but it doesn't have to be an ugly duckling, either. According to industrial designers Joseph Palma and J. Gordon Knapp, "Too often machine tools and other industrial goods just evolve to meet a need, with little or no thought to how the product looks or whether it is as functional as it might be." They maintain that industrial products should be designed for eye appeal and that the ideal redesign is one which adds to the usefulness of the product as well as to its appearance. The firm (Palma-Knapp Inc., River Forest, Ill.) employs what it calls the "value analysis" approach: "If design can add more value to a product at the same cost, or maintain value

while lowering the cost, obviously such a design is profitable."

One example cited by Palma-Knapp is a 30-in. router (1) redesigned for Onsrud Machine Works Inc. Cast doors were replaced by sheet-metal panels, which reduced machining. Controls were regrouped for easy access, safety, and convenience. Surface finishing of the work-table was simplified. Cost of manufacturing was reduced 15 per cent, and the new appearance increased sales by 100 per cent.

A metering pump designed for Hills-McCanna Co. (2) has an extruded aluminum shroud, which conceals working parts and enhances appearance.



2.

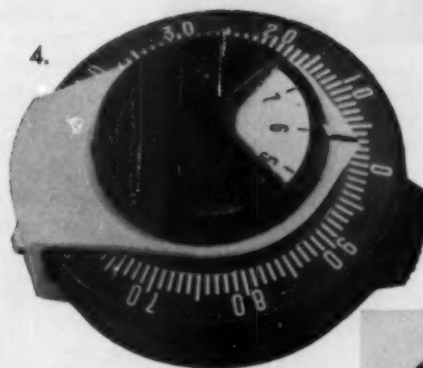
In the before-and-after pictures:
A pH meter redesigned for Coleman Instruments Inc. provides larger controls for better manipulation and an improved dial for greater visibility (3). Styling provides strong product differentiation.

Visibility was increased, and manufacturing cost was decreased, in redesign of the microdial (4) for Borg Equipment Div., Amphol-Borg Electronics Corp.

The Mercury industrial tractor was redesigned for low-volume production, requiring no special tooling (5).



3.



4.



5.



Cold-soaked at -25°F , Lycoming's multifuel compression-ignition engine starts without the use of external accessories. Glow plugs, directly in the open combustion chamber, are largely responsible for cold-start capability.

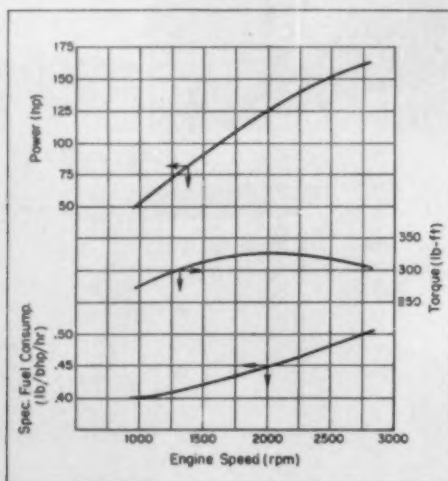
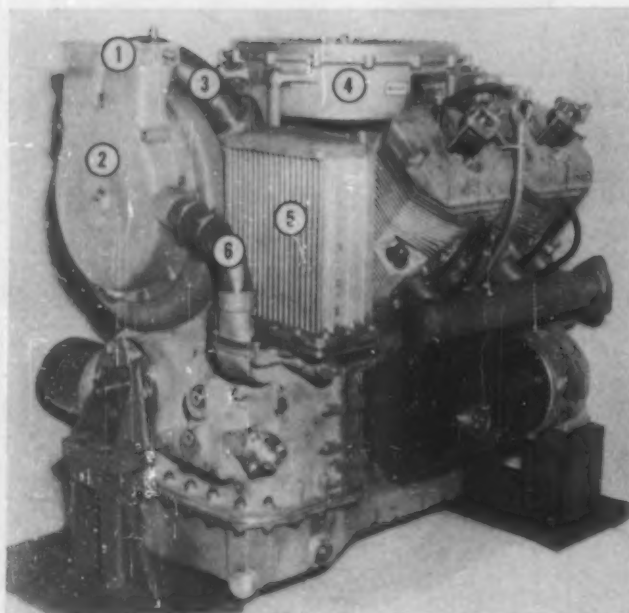
Army Tests Two-Cycle Multifuel Engines

STRATFORD, CONN.—A major development in piston-engine design has been revealed by the Army Ordnance Corps in the form of a new lightweight, air-cooled, multifuel engine that is capable of starting unaided at temperatures as low as -25°F .

Developed by Avco Corp.'s Lycoming Div., the new automotive-type powerplant is a two-cycle compression-ignition engine intended primarily for use in light tracked and wheeled military vehicles. It has only three principal moving parts per cylinder.

According to Ordnance officials, the engine is as light and compact as a conventional gasoline engine of equal horsepower, but uses only about 60 per cent as much fuel. Loop-scavenged, it lacks many components used in conventional piston engines, including most of the high-mortality parts such as valves, valve springs, valve rockers, cam shafts, and tappets. The complete cylinder is an integral aluminum casting with a porous chromium-plated bore. Freely rotating pistons are used to equalize the heat which, in loop-scavenged engines, is unsymmetrical. Warping, thermal stresses, unequal expansions, and out-of-roundness of pistons and cylinders are thus minimized.

Four and eight-cylinder versions of the new engine are currently in various stages of development and testing. Ordnance Corps projections include a complete family of operational engines ranging from four to eight cylinders and from 160 to 325 bhp. The engine's 90 degree "V"



Four-cyl performance curves are shown above; components (left) are: 1. Scavenge-blower inlet. 2. Scavenge-air blower. 3. Blower-to-engine air duct. 4. Cooling-fan shroud. 5. Oil cooler. 6. Crankcase breather.

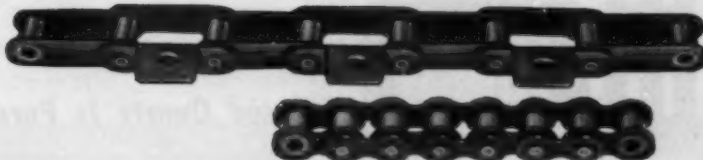
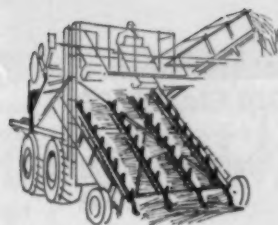
NEW

Rex Redi-Lube

Chain

lubricates

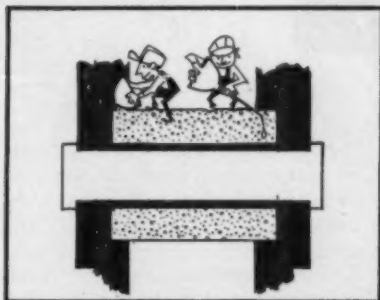
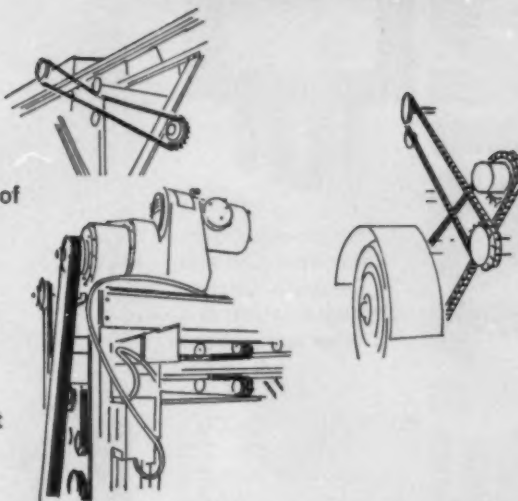
itself!



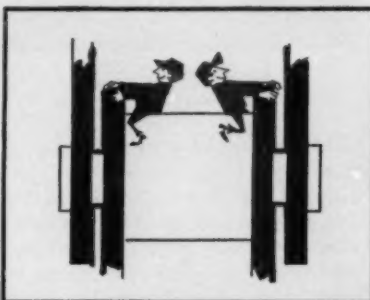
It lubricates itself! You can use it where you need the strength, the wear life, and the quiet, precision operation of a roller chain. But it reduces the need for repeated lubrication, which is so important to chain life.

Now, new Rex Redi-Lube Chain puts full life into drives and conveyors that can't be regularly lubricated—provides protection against tough service conditions such as dust, dirt or moisture—ideal for open and exposed drives.

Find out how new Rex Redi-Lube Chain can help you get longer service life from your equipment. Call your Rex distributor, write, or mail the coupon below.

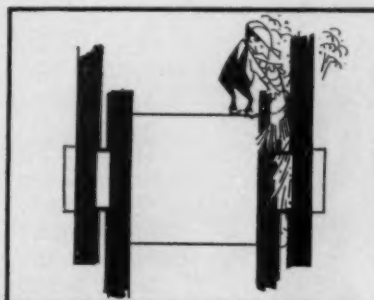


COMBINES ROLLER CHAIN PERFORMANCE WITH SELF-LUBRICATION. A heavy oil-impregnated, sintered steel bushing replaces the conventional roller and bushing of standard roller chain—provides "self-feed" lubrication between bushing, pin and sprocket teeth—assuring constant protection against corrosion, abrasion and friction.



MINIMIZES TIGHT JOINTS. Tight joints are primarily caused by the link plates "backing off" the bushing.

Rex Redi-Lube is designed to prevent tight joints. The heavy-walled, hardened bushing, with its accurately controlled press-fit in the link plates, locks the plate on the bushing—assures true link plate alignment.



PROVIDES SELF-CLEANING ACTION. Designed clearances between link plates allow dirt to work free, reducing abrasive wear and binding.

INTERCHANGEABLE WITH ASA ROLLER CHAIN. Couples with ASA roller chain and operates over the same sprockets.

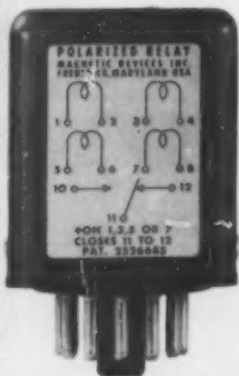
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ENGINEERING NEWS

configuration results in a compact package with weights ranging from 3 to 4 lb per bhp. The four cylinder model, for example, including complete cooling system and accessories, develops 160 gross bhp, weighs 600 lb. It measures about 30 in. long, 30 in. wide, and 28 in. high. The eight-cylinder model develops 325 gross bhp, weighs less

than 1000 lb, and measures 30 by 28 by 45 in.

According to Ordnance spokesmen, the engine has been carefully designed to meet all military requirements and can stand considerable abuse and battle damage. Field changes of complete cylinders will take less than 30 minutes. No engine adjustment is needed to switch from one fuel to another.

Fused Quartz Is Purest Yet



When heated in a flame, tubing made from General Electric's fused quartz sags less than that made from imported materials. Now in production, the ultrapure quartz is the first made from domestic raw material.

CLEVELAND—Using new techniques, scientists at General Electric Co., Lamp Glass Dept., are producing the purest fused quartz ever made. And they are working with poor quality raw material—the silicon dioxide that is domestically available.

Previously, pure fused quartz was produced from imported raw materials, the only reliable sources of supply being Brazil and Madagascar. The advantages of higher purity and of being able to use domestic supplies will be of major significance to defense, space, electronics, lamp, and other industries, according to Ernest A. Howard, general manager of GE's Lamp Glass Dept.

High-purity fused quartz will be particularly beneficial in research

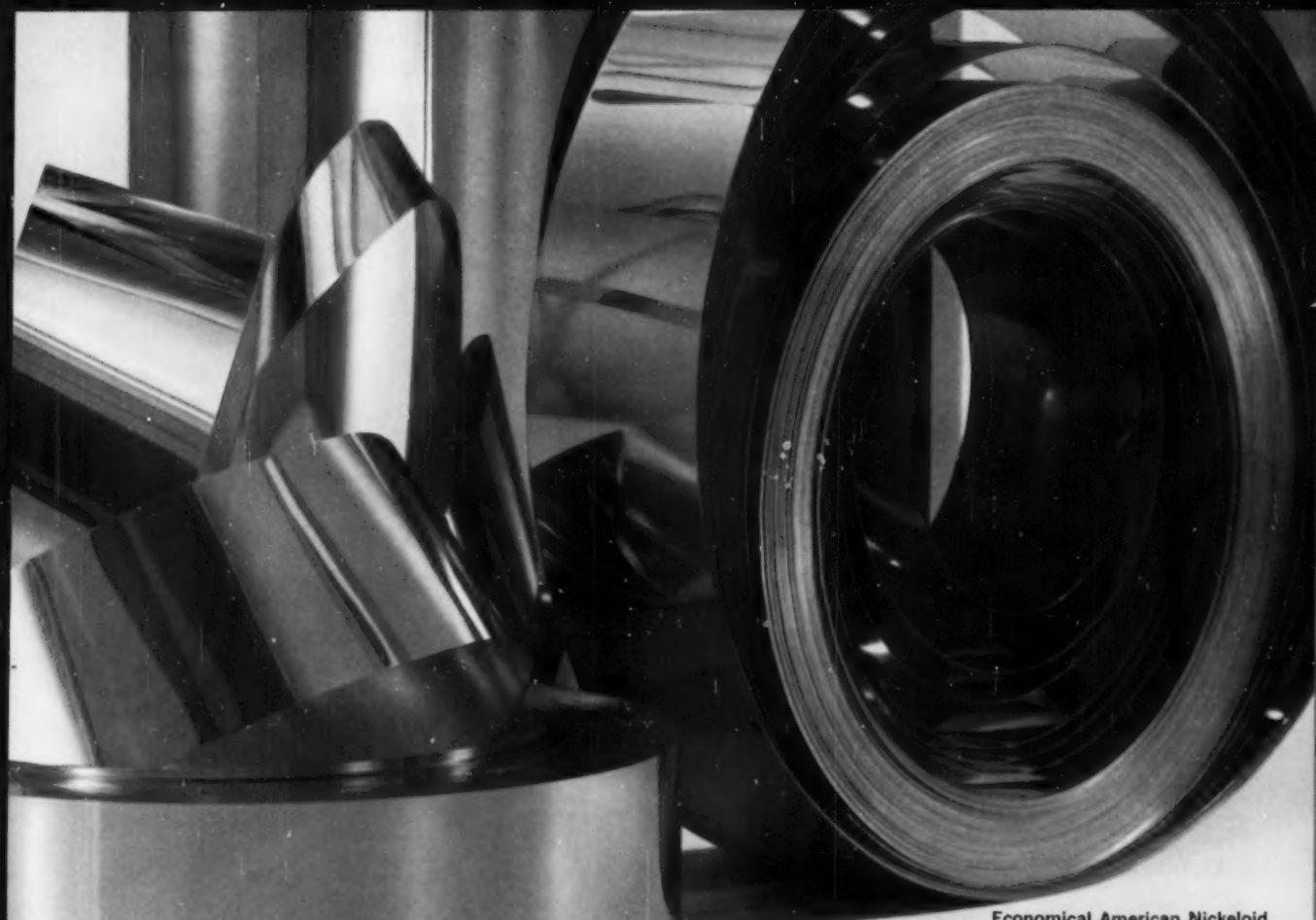
and development laboratories where, in many cases, even the smallest trace of impurities presents a problem, Mr. Howard continued. The semiconductor industry will be particularly benefited by the much lower content of alumina and boron, previously a major problem in the manufacture of transistors.

The new quartz has better thermal resistance and will withstand high temperatures for longer periods of time. Tests show, for example, that the material will deform at less than one-half the rate of the former quartz when subjected to temperatures of 1200 C and higher. In addition, tubing and rod produced from the domestic source will devitrify more slowly, and not cloud up as much at high temperatures.

How to be Elegant though Thrifty

Finding it hard to say "Beauty" and "Economy" in the same breath? Then think in terms of American Nickeloid pre-plated metals! You'll open up a whole new world of product elegance . . . but leave costly

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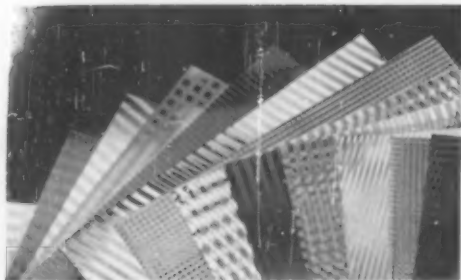


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stripes . . . all built into the metal before
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Meetings and Shows

Nov. 30-Dec. 1—

Institute of Radio Engineers. Vehicular Communications Conference to be held at the Hotel Leamington, Minneapolis. Additional information is available from IRE, 1 E. 79th St., New York 21, N. Y.

Dec. 2-5—

Visual Communications Congress to be held at the Biltmore Hotel, Los Angeles. Sponsors are Society of Reproduction Engineers, American Institute for Design and Drafting, and American Records Management Association. Additional information is available from Congress headquarters, 18465 James Couzens Highway, Detroit 35, Mich.

Dec. 7-8—

Society of the Plastics Industry Inc. Ninth Plastic Film, Sheet, and Coated Fabrics Conference to be held at the Pierre Hotel, New York. Further information is available from SPI headquarters, 250 Park Ave., New York 17, N. Y.

Dec. 12-14—

Eastern Joint Computer Conference, to be held in Washington, D. C., under the sponsorship of the American Federation of Information Processing Sciences (Institute of Radio Engineers, American Institute of Electrical Engineers, and Association for Computing Machinery). Additional information can be obtained from IRE headquarters, 1 E. 79th St., New York 21, N. Y.

Dec. 12-15—

American Society of Agricultural Engineers. Agricultural Engineering Exposition (Dec. 12-14) and ASAE Winter Meeting (Dec. 13-15) to be held at the Palmer House Hotel, Chicago. Further information can be obtained from society headquarters, St. Joseph, Mich.

Dec. 18—

Institute of the Aerospace Sciences. Wright Brothers Lecture to be given at the Smithsonian Institution, Washington, D. C. Additional information can be obtained from IAS, 2 E. 64th St., New York 21, N. Y.

Jan. 8-12—

Society of Automotive Engineers Inc. 1962 Automotive Engineering Congress and Exposition to be held at Cobo Hall, Detroit. Additional information can be obtained from society headquarters, 485 Lexington Ave., New York 17, N. Y.

Jan. 22-24—

Institute of the Aerospace Sciences. Thirtieth Annual Meeting to be held at Hotel Astor, New York. Further information can be obtained from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

Jan. 22-25—

National Plant Engineering & Maintenance Show to be held at Convention Hall, Philadelphia. Further information can be obtained from show managers, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 29-Feb. 1—

American Society of Heating, Refrigerating and Air-Conditioning Engineers. Semiannual Meeting to be held at the Chase-Park Plaza Hotel, St. Louis. Additional information can be obtained from ASHRAE headquarters, 345 E. 47th St., New York 17, N. Y.

Jan. 30-Feb. 2—

Society of Plastics Engineers Inc. Annual Technical Conference to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information can be obtained from John E. Parks, H.P.M. Div., Koehring Co., 512 Empire Bldg., Pittsburgh 22, Pa.

Feb. 6-8—

Society of the Plastics Industry Inc. Seventeenth Reinforced Plastics Division Conference to be held at the Edgewater Beach Hotel, Chicago. Further information is available from SPI headquarters, 250 Park Ave., New York 17, N. Y.

March 4-8—

American Society of Mechanical Engineers. Gas Turbine-Process Industries Conference to be held at Shamrock Hilton Hotel, Houston. Further information is available (Please turn to Page 42)

ENGINEERING NEWS

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DATA PROCESSING

Circle 220 on Page 19

(Continued from Page 39)

from Meetings Dept., ASME, 345 E. 47th St., New York 17, N. Y.

Short Courses and Symposia

Seminars on Numerical Control will be conducted jointly by the National Machine Tool Builders' Association and American Machine Tool Distributors Association. Dates and locations are as follows: Dec. 4-5, Biltmore Hotel, Los Angeles; Dec. 7-8, Jack Tar Hotel, San Francisco; Dec. 18-19, Statler Hilton Hotel, St. Louis; Jan. 8-9, Statler Hilton Hotel, Cleveland; Jan. 11-12, Netherlands Hilton Hotel, Cincinnati; Jan. 22-23, LaSalle Hotel, Chicago; Jan. 25-26, Sheraton-Cadillac Hotel, Detroit; Feb. 5-6, Marriott Motor Hotel, Philadelphia; Feb. 8-9, Hotel Kenmore, Boston; Feb. 19-20, The Dinkler Plaza, Atlanta; Feb. 22-23, Hotel Adolphus, Dallas. Other seminars will be scheduled. Further information is available from Mr. Arthur Hachten, Director of Information Services, National Machine Tool Builders' Association, 2139 Wisconsin Ave., Washington 7, D. C.

Dec. 11-13—

Metal Joining Symposium to be held at Pennsylvania State University. Papers presented on each of the three days will follow a particular theme: High-strength and high-temperature brazing alloys, high-strength material welding, and stress analysis of joints. Advantages and limitations of the various joining methods will be discussed. Panel discussions and question periods will be held each day. Further information is available from Conference Center, Pennsylvania State University, University Park, Pa.

Jan. 9-11—

Eighth National Symposium on Reliability and Quality Control to be held at the Statler Hilton Hotel, Washington, D. C. Technical sessions will cover reliability and design techniques, reliability prediction and measurement, mathematics and reliability models, statistical techniques, reliability testing, main-



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tainability, quality control and reliability, reliability programs and management, reliability and quality control education, and reliability training sessions. Additional information can be obtained from Mr. A. R. Park, Mail Stop No. 729, Westinghouse Electric Corp., P. O. Box No. 1897, Baltimore 3, Md.

Jan. 11-12—

Electrical Engineering Refresher Course to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 15-19—

Seminar on Simulation and Mathematical Programming for industrial engineers, to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 16-17—

Engineering Institute on Industrial Adhesives Applications to be held at University of Wisconsin. Technical sessions will cover basic principles of adhesive bonding, some important applications of adhesives, design of joints for adhesive bonding, equipment requirements for adhesive bonding, evaluation techniques for adhesives, and principles of adhesive formulation. Additional information can be obtained from William W. Wuerger, Institute Coordinator, Engineering Dept., Extension Div., University of Wisconsin, Madison, Wis.

Jan. 18-19—

Industrial Power Systems Seminar to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 24-26—

Second Symposium on Thermophysical Properties to be held in Princeton, N. J., under the auspices of the Heat Transfer Div. of the American Society of Mechanical Engineers. Further information can be obtained from ASME, 345 E. 47th

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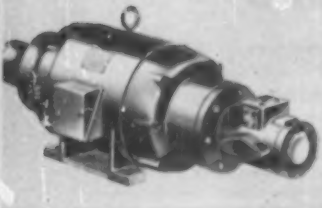
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MOTOR PUMPS—A 5 HP, double-end motor pump is used on this Burgmaster. The complete Vickers motor pump line offers single, double, two-pressure and two-stage pumps. Use of these motor pumps conserves space and eliminates alignment problems between pump and motor. Details are available in Catalog 5001C.

POWER PACKAGES—A complete Vickers 30-gallon hydraulic power supply was custom-designed and built for this machine. Vickers offers standard and custom power packages to meet every type of application need. Get details from your Vickers application engineer.

DIRECTIONAL VALVES—Two types of directional valves—solenoid operated and solenoid controlled, pilot operated—are used on this Burgmaster machine. The complete Vickers line of two- and four-way directional control valves is described in Catalog 5001C.

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Machinery Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
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Circle 224 on Page 19

ENGINEERING NEWS

St., New York 17, N. Y.

Jan. 25-26—

Research Management Conference to be held at University of Wisconsin. Additional information is available from C. F. Hurc, Conference Co-ordinator, University Extension Div., Dept. of Engineering, University of Wisconsin, Madison 6, Wis.

Jan. 29-Feb. 2—

Short Courses on Measurement Engineering to be held at Arizona State University. Theme of the courses is "How To Obtain Valid Data on Purpose;" they consist of a lecture program and a concurrent experimental program. About half of the lectures are on basic physical principles on which transducers are based and on fundamental measurement theory, including static and dynamic system behavior and the correlation between them. The other lectures are devoted to measurement problems and approaches in specific areas. Additional information is available from Prof. Peter K. Stein, Associate Professor of Engineering, Measurement Engineering Center, Arizona State University, Tempe, Ariz.

Jan. 29-Feb. 8—

Short Course on Quality Control by Statistical Methods to be held at the University of Illinois. Additional information can be obtained from University of Illinois, Dept. of Mechanical and Industrial Engineering, Urbana, Ill.

Jan. 30-Feb. 1—

Seminar on Standardization to be held at the Barbizon Plaza Hotel, New York. The seminar will cover fundamental philosophy of organized standardization and an analysis of the basic approach to the formation of standards; a review of standardization as an integral function of management and the organization of standards work, particularly on the company or corporate level; and various forms of applied standardization techniques, tools of the standards engineer, and the principles of writing standards and specifications. Further information is available from Dr. John Gaillard, 135 Old Palisades Rd., Fort Lee, N. J.

MACHINE DESIGN



ANTTI RAIHA, CHIEF ENGINEER, BURGMASER CORP. SAYS:

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"... in order to control tool penetration and table positioning where location tolerances must be held to .001-inch. We've worked with Vickers hydraulic power systems since 1951, beginning with our automatic hydraulic models, we are increasing our activity in this area as the demand for turret drilling machines and tape controlled machines grows.

"In addition to the machine shown, we use Vickers hydraulics on seven different standard models as well as on many specially designed variations of these standard machines. We rely on Vickers hydraulic power systems, not only for their unusually high quality, but because they are easy to maintain and we have the additional assurance of the availability of their worldwide service organization.

"Because Vickers application engineers have given us close cooperation and have a thorough understanding

of our requirements, we've been able to develop systems that provide long, trouble-free life."

Whether you are building standard or special purpose machinery, your power and control requirements can be met precisely and economically by the proper application of hydraulic systems. Typical Vickers components and systems used by Burgmaster are shown on the facing page. They are part of the broadest line of top quality hydraulics available anywhere.

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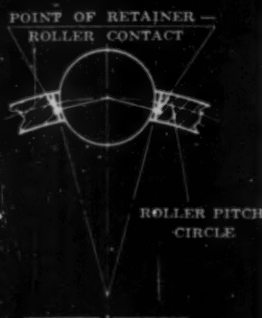
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Circle 224 on Page 19



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Integral seals which retain lubricant and keep contamination out of critical bearing areas insure the superior performance expected with McGill's exclusive design advantages. Sealed CAGEROL needle bearings are ideal where auxiliary sealing is cumbersome and expensive and are especially serviceable where relubrication is impractical.

The combination of sealing and positive roller control produces a new standard of service life. Other CAGEROL design features include crowned rollers to prevent "end-loading" and black ferrous oxide retainer finish to absorb and retain lubricant.

CAGEROL bearings offer definite performance superiority where shaft misalignment and speeds exceed the limitations of ordinary end-guided needle bearings. Often up to 10 times more life can be expected. Interchangeable with ordinary needle bearings. Also available in unsealed series.

Specify CAGEROL bearings to improve your machine performance.

Tapered retainer pockets assure proper roller guidance. Designed so retainer OD falls outside roller pitch circle to establish roller and crossbar contact on a concentric plane below center. This insures balanced roller support and eliminates corner wear from edge loading inherent in other designs.

For data on the complete line of McGill heavy duty needle roller bearings, send for bearing catalog No. 62.



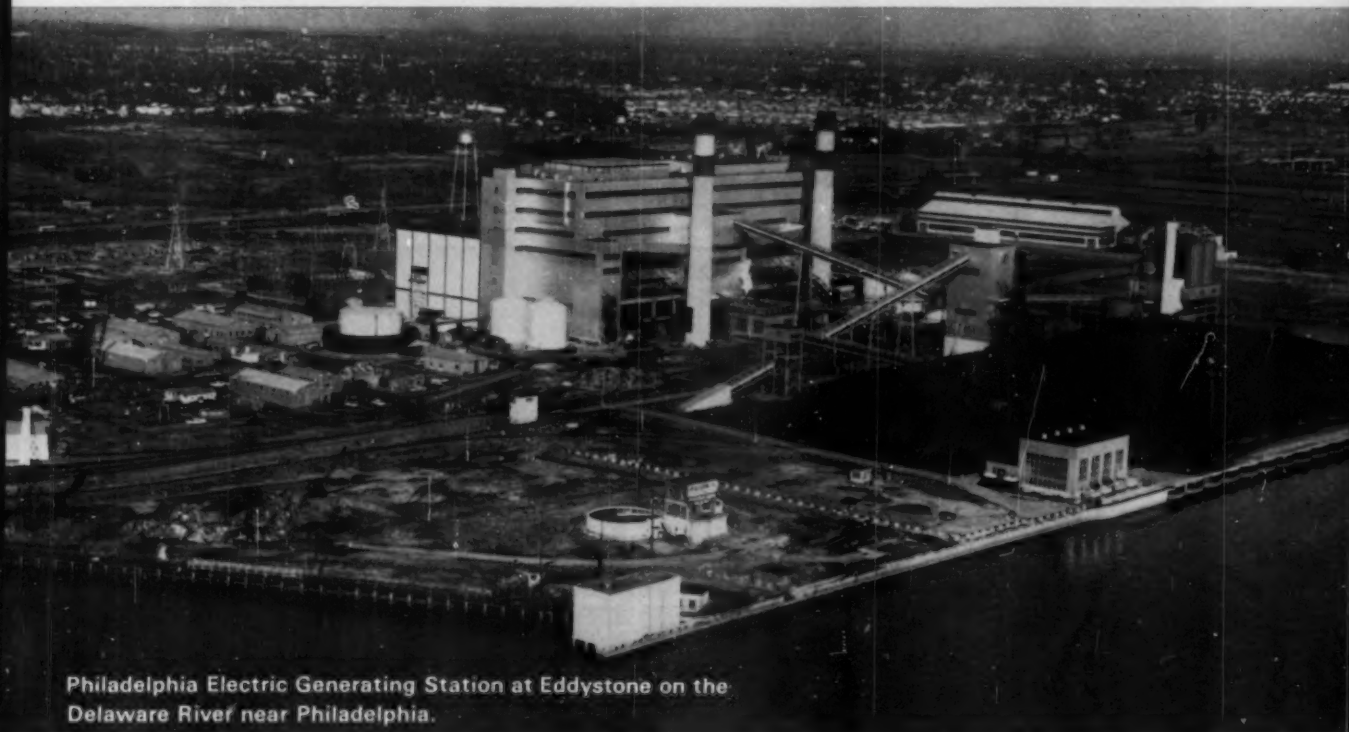
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WORLD'S MOST EFFICIENT POWER STATION SPECIFIES MOST EFFICIENT TUBE FITTINGS

Swagelok®

Philadelphia Electric Company's new Eddystone Station is an engineering achievement of which Americans can be proud. Representing a major breakthrough in the power industry, the Eddystone Electric Generating Station was designed as the world's most efficient power plant. This improvement in efficiency has been achieved by generating steam at a supercritical pressure of 5000 pounds per square inch and a temperature of 1200° F.

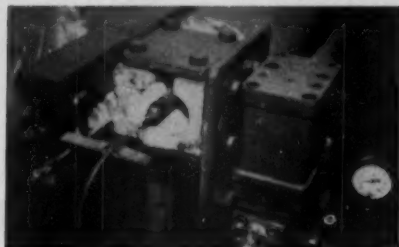


Philadelphia Electric Generating Station at Eddystone on the Delaware River near Philadelphia.

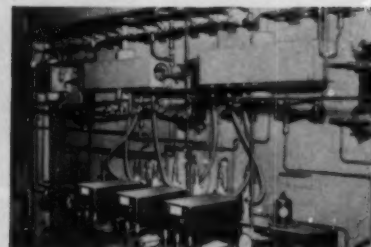
Housing two 325,000 kilowatt turbine generators, this giant station can produce enough power to supply the residential needs of a city of five million people.



Control Center for Eddystone Plant Operation.



Swagelok Tube Fitting used as a thermocouple connector on main steam header #1 for boiler control. Operating conditions: Steam at 5000 psig — 1200° F.

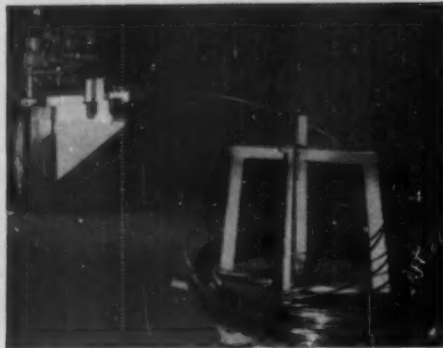
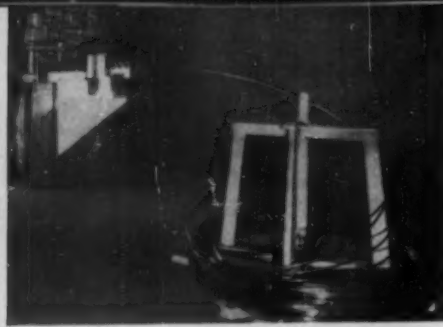
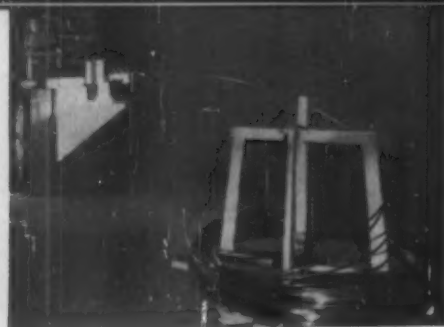


Swagelok Tube Fittings used in control systems of supercritical pressure boiler.

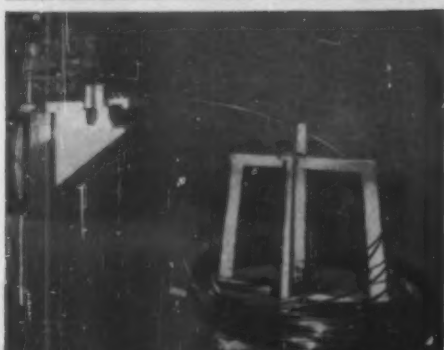
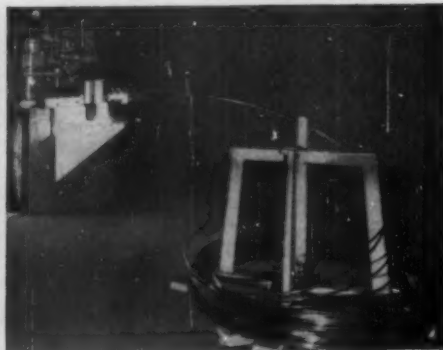
Swagelok® TUBE FITTINGS

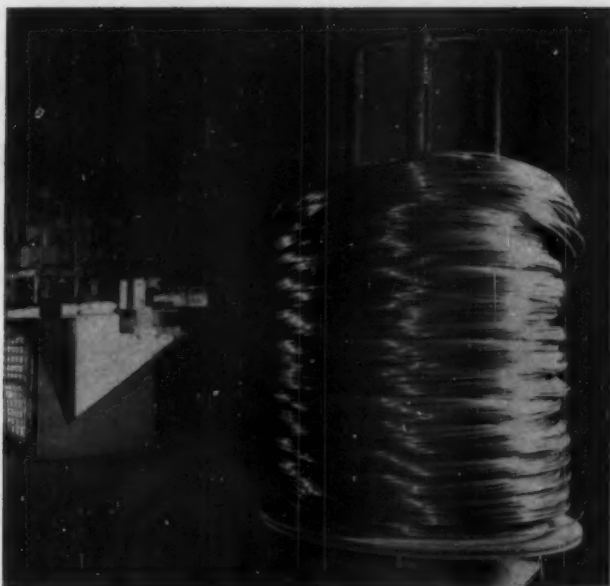
Crawford Fitting Company, 884 East 140th Street, Cleveland 10, Ohio • Crawford Fittings (Canada) Ltd., Niagara Falls, Ontario, Canada

Circle 226 on Page 19



Why set up ten times





...when once will do ?

It's a simple matter to add up the savings heavy-weight wire coils can give you. How much time does it take you to shut down a machine and start a new coil through? Multiply that by the number of times you have to do it in an 8-hour shift. Then figure that as much as 90% of that lost time is sheer waste. Because you could be using AS&W heavyweight coils that contain up to ten times as much wire in one continuous length. **Other savings:** less handling, less storage space needed, even lower scrap loss. Heavyweight coils aren't the only road to cost reduction: *American Steel and Wire offers a dozen different wire packages.* One of them is designed just right for your operation. Let us look at your set-up and recommend the best package . . . a simple step to increased production. Call our nearest sales office or write American Steel and Wire, Dept. 1490, Rockefeller Building, Cleveland 13, Ohio.

Innovators in wire



**American Steel and Wire
Division of
United States Steel**

General Electric Makes Eddy-current-coupling Drives

And they're dependable drives. The complete line includes water-cooled and air-cooled eddy-current couplings. We call them **KINATROL** drives. Ratings are from 1 to 150 horsepower, operating from standard a-c power.

A General Electric **KINATROL** drive is not just another eddy-current coupling. For instance, in the water-cooled coupling, water control is packaged. You'll see much less external piping. Furthermore, the coupling is protected from flooding—and the air gaps are dry, preventing corrosion.

KINATROL couplings are compact, field proven and dependable. General Electric has had a good deal of experience in the engineering, manufacturing, and application of packaged adjustable-speed drives. And we know how important service is to a customer.

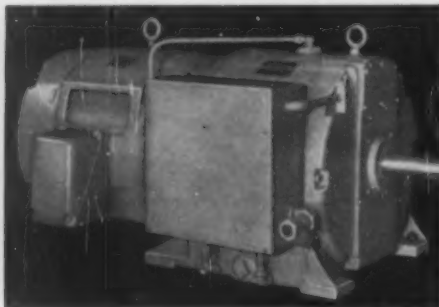
KINATROL —a good product, with the kind of service you can depend on. Please call your nearest General Electric Sales Office for further details.

*Trademark of General Electric Company

821-07



AIR COOLED, 7-1/2 to 100 HP



WATER COOLED, 25 to 150 HP



AIR COOLED, 1 to 5 HP

DIRECT CURRENT MOTOR AND GENERATOR DEPARTMENT

GENERAL  ELECTRIC

ERIE, PENNSYLVANIA

Circle 228 on Page 19

ALLEN INTRODUCES *LOKON*

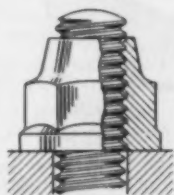
NEW general-purpose LOCKNUT holds positively tight even after repeated on-off cycles . . . provides a "commercial" locknut in the "aircraft" quality range . . . offers strength without bulk for heavy-duty applications

True to its name, the LOKON nut locks on a companion threaded member with a can't-shake-loose grip . . . holds indefinitely against heaviest impact and vibration. Because the basic design allows adequate deformation of the "turret top" without overstressing any portion of the periphery, "LOKONS" are highly resistant to fatigue failure. And, through closely controlled heat treatment, a degree of elasticity is achieved which permits re-use time after time without significant impairment of the locking action.

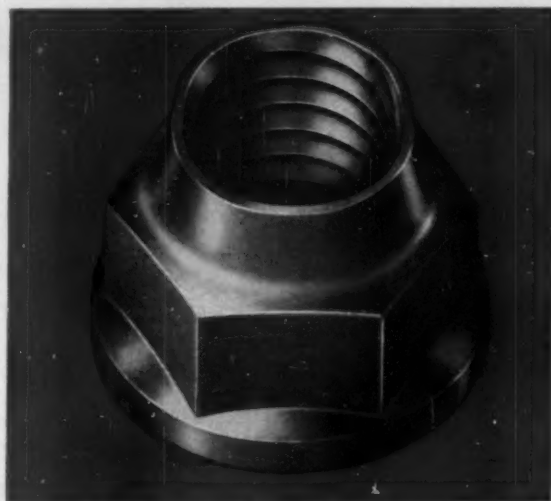
LOKON locknuts assemble fast and easy . . . start with finger spinning . . . tighten smoothly . . . lock at any point as soon as the threads in the elliptical section are fully engaged, and are readily removed without damage to the nut or mating part. Investigate LOKON at the first opportunity. Discover the many ways this major development in locknuts can save you time and cut costs. Test samples* and engineering data are yours for the asking. And, for prompt, off-the-shelf delivery, call your nearby Allen Distributor who carries full stocks of LOKON locknuts as well as dependable Allen hex-socket screw products.

*Currently offered in sizes from No. 10 through $\frac{1}{2}$ " UNC and UNF threads. Other sizes available soon.

HOW *LOKON* LOCKS . . .



The threads in the tapered crown of the nut are slightly distorted from the round. When assembled to a companion threaded member, this out-of-round condition causes the nut to resist free entry of the mating part. As the metal flexes in an effort to conform to the circular pattern of the male threads, friction on the flanks of the nut threads is increased. The compressive forces exerted as a result of this diaphragmatic flexing action produce a positive, powerful locking grip.



Only "LOKONS" offer all these extras . . . all without EXTRA COST!

ONE-PIECE, ALL-METAL CONSTRUCTION—The LOKON design requires no segments, inserts or other auxiliary locking devices.

HIGH-GRADE ALLOY STEEL—Heat treated to Rc 26/30. Imparts tensile strength in excess of 250,000 psi and provides lasting spring tension for unlimited re-usability.

CLASS 3B THREADS—Comply fully with specification MIL-S-7742 and H-28 Handbook.

BUILT-IN FLANGE—Large-area bearing surface saves washer cost, speeds assembly, reduces indentation. Face of flange is held square with threads to insure even distribution of stresses throughout the flange and thread area.

DIMENSIONAL ACCURACY—Allen "pressur-forming" processes control grain flow, hold tolerances to consistently close limits, and produce fully-formed hex corners for sure-grip wrenching.

HIGH TEMPERATURE SERVICE—Performance is unaffected at temperatures to 550°F.

MILITARY SPECIFICATIONS—LOKON locknuts fulfill the performance requirements of MIL-N-25027.



ALLEN

THE ALLEN MANUFACTURING COMPANY • HARTFORD 1, CONN., U.S.A.
PLANT AT BLOOMFIELD, CONN. • WAREHOUSES IN CHICAGO, CLEVELAND, LOS ANGELES

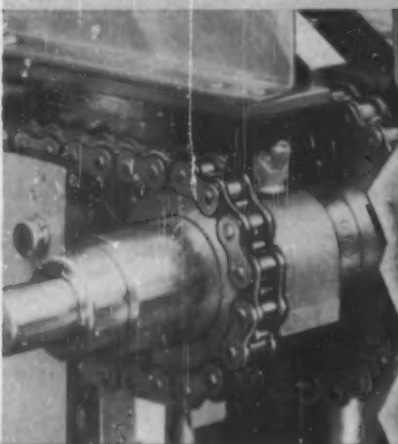


FOR OVER 50 YEARS. MAKERS OF FAMOUS ALLEN SOCKET SCREW PRODUCTS



STANDARD ROLLER CHAINS

ACME chains are available in sizes from $\frac{1}{4}$ " pitch, $\frac{1}{8}$ " width to $2\frac{1}{2}$ " pitch, $1\frac{1}{2}$ " width.

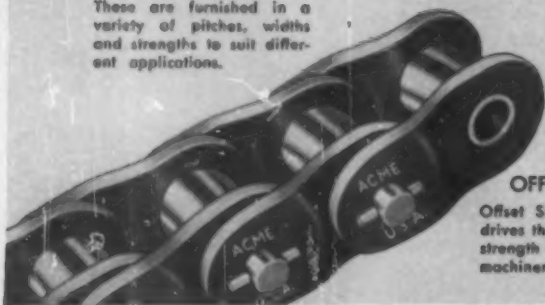


This shows a typical installation with positive power transmission where long life is essential.



LEAF CHAIN

These are furnished in a variety of pitches, widths and strengths to suit different applications.

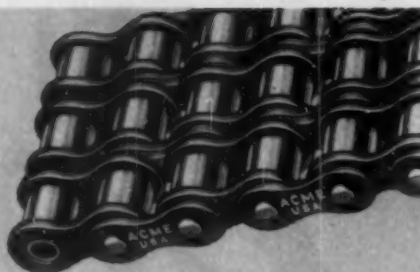


OFFSET CHAIN

Offset Side Bar Chains for drives that require herculean strength in construction machinery and oil fields.

MULTIPLE ROLLER CHAINS

Multiple roller chains of double, triple and quadruple widths in all standard pitches in riveted types are ordinarily carried in stock — multiple chains up to 6 strands or wider can be furnished.



There's an ACME ROLLER CHAIN for every POWER TRANSMISSION REQUIREMENT

ACME Roller Chains are designed and built to perform each specific job with maximum efficiency and economy. Sprocket ratio, chain impact, tension, drive speed and other factors are determined, not on the drawing board alone, but in the field where ACME Engineers observe and test chains at work while new equipment is being designed. In that way, ACME chains are made to deliver positive power transmission with economy and dependability under all loads at all times.

For maximum performance at low transmission cost, be sure to specify ACME Roller Chains. They will give you the most value for your chain money. Call your ACME Distributor.



Write Dept. 6-P for new illustrated 106 page catalog with engineering section.



EXTENDED PITCH CHAIN

Extended pitch chains are becoming increasingly more popular in many industries where high grade finished roller chains are required, at a lower cost than the standard pitch chains.



Spring RELIABILITY measured to less than 0.1% at temperatures from -85°F to 185°F

WHAT TYPE OF PRODUCT REQUIRES SUCH SPRING ACCURACY?

The heart of a precision aircraft altimeter contains a diaphragm and a single torsion spring. Specifications of the spring call for the rate to be constant within 0.1% over the entire deflection range and at all temperatures between -85°F and 185°F; hysteresis must be below 0.03%; and no measurable creep can be tolerated in 72 hours at maximum deflection and maximum test temperature.

HOW PROOF OF ACCURACY WAS DETERMINED

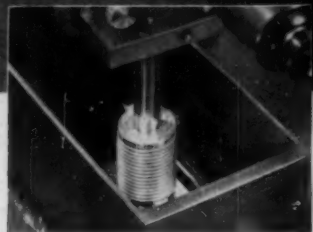
Because no equipment was commercially available to measure torsion springs to this extreme accuracy, A.S.C. Research and Development Center shared with the customer the cost of developing a special tester. Each spring is rotated in hot and cold liquid while its torque is balanced against a precision torque wire. Sightings of deflection through a transit, connected with the torque wire, are made on a scale mounted 14 feet distant. Data obtained from this unique apparatus give the spring user proof that each lot of springs falls safely within his ultra-precise limits.

Subsequently, the equipment has been used to calibrate several other torsion springs with ultra-precise specifications.

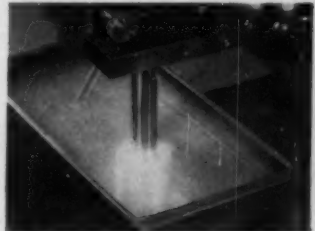
While your springs and spring-like parts may not require such precision, here is ample assurance that A.S.C. can make *your* springs with predictable performance in the degree desired.

May we discuss your needs?

Broad treatment of the subject of spring reliability is contained in a recent issue of A.S.C.'s house organ, *The Mainspring*. Send for your copy.



Altimeter instrument spring is secured in tank fixture ready for testing under simulated operating conditions.



Spring is rotated in hot or sub-zero liquid and its torque balanced against a calibrated wire.



Minute changes in deflection are read through a transit on a scale 14 feet distant.

Associated Spring Corporation



General Offices: Bristol, Connecticut

Wallace Barnes Division, Bristol, Conn. and Syracuse, N. Y.
F. N. Manross and Sons Division, Bristol, Conn.
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Get your lead out and test new ozaclear

Transparentized Tracing Paper by OZALID
with a tough, non-fracturing surface that gets
clear-as-a-bell prints.

Get your pen out, too! Contact your Ozalid man for samples and see for yourself how well this new Ozalid tracing vellum takes the lead and ink...how well it reproduces *even when abused*. Crease it . . . make multiple erasures . . . then go ahead—crumple it in a ball. Flatten it out and make a reproduction from this much-abused OZACLEAR. Now try the

same thing on your present tracing sheet. Clear-as-a-bell OZACLEAR gives high repro speed, excellent contrast, fine clear-as-a-bell prints. A new companion product to Ozalid Ozatrace® vellum and Duratrace® drafting film. For more information, samples, write: OZALID, Dept. 215, Johnson City, N. Y. In Canada: Hughes-Owens Co., Ltd., Montreal.

OZALID
— WE REPEAT —
OZALID
DIVISION OF GENERAL ANILINE & FILM CORPORATION

When superhard-finished aluminum shows no wear in six years . . .



ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

When superhard-
finished aluminum
shows no wear
in six years

that's Alcoa Total Ability at work!



Molding earth-mover tires takes 1,000 psi minimum at 200 to 325°F for as long as 12 hours straight. Six years ago, the world's largest tire tread mold insert, 36.00 x 41—an aluminum casting—was hard-coated by the Alcoa® Alumilite® process. No wear has been found and none is expected.

Originated and developed by Alcoa research, the Alumilite process gives aluminum a "file-hard," thick, dense coating. Formerly, passenger-car tire molds wore past tolerances in just 30 days. With Alcoa's Alumilite Hard Coating, their service life is indefinite. Other coatings hard enough to protect as well cost about *three times* as much.

At work or on display, aluminum takes a thousand

finishes. Electrochemical processes like Alumilite guard it from weather and wear. The rainbow's colors grace Alcoa Aluminum through surface treatment or finishing. It's textured a hundred ways. A 48-page, full-color booklet, *Finishes for Alcoa Aluminum*, is available. Send for your free copy.

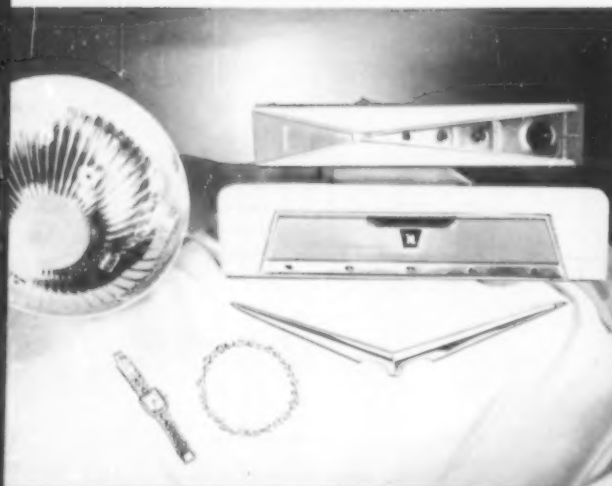
Shapes of aluminum in endless variety also come from Alcoa's forges, foundries, rolling mills and extrusion presses. Truly, imagination's the only limit when *Alcoa Total Ability* works aluminum for you. Learn the difference it can make in *your* products (and profits!). Call your nearby Alcoa sales office, or write: Aluminum Company of America, 856-L Alcoa Building, Pittsburgh 19, Pa.

*Trade Name of Aluminum Company of America



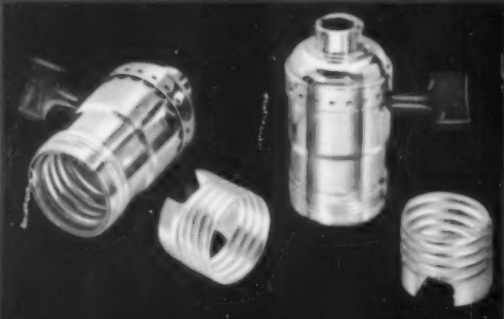
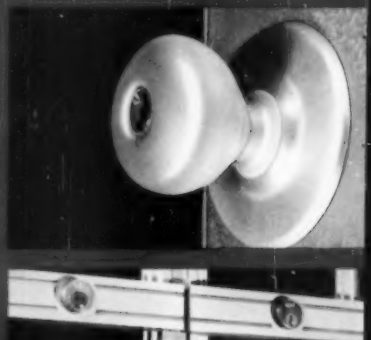
ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA



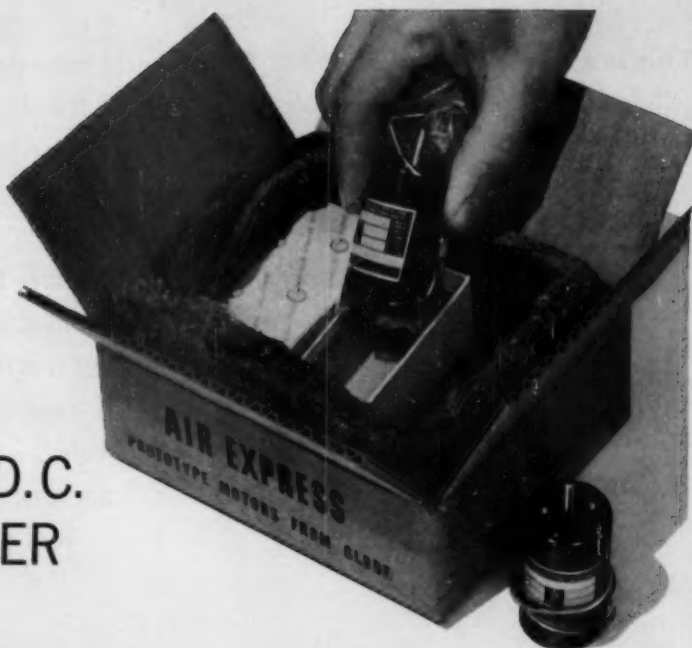
Alcoa Aluminum—the metal with a limitless number of applications—can be finished by every mechanical, chemical and electrochemical method used on other metals . . . and more!

You can polish it, blast it, buff it, burnish it, hone it, emboss it, coin it,peen it, etch it, bright-dip it, anodize it, electrobright-dip it, paint it, lacquer it, enamel it, porcelain-enamel it, laminate it, metallize it, satin finish it.



MINIATURE A.C. & D.C. MOTOR AND BLOWER PROTOTYPES

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When you need precision miniature motors, gearmotors, or blowers **quickly**, call Globe! We stock limited quantities of many sizes and types—both a.c. synchronous and induction (60 and 400 cycle) and d.c., p.m. and wound field for meeting your prototype needs. While we can't meet every requirement from stock, we can probably tide you over until we can furnish you the exact motor or blower. Special prototypes are generally available in 2 to 4 weeks. Check your needs against the partial stock listing below, then ask your local Globe representative or call the factory direct for immediate service. For details, request Bulletin 24 from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio. 222-3741.

A. C. MOTORS

TYPE SC. $1\frac{1}{8}$ " dia. x $1\frac{1}{2}$ "
115 v.a.c., 60 cycle, 1 phase,
hysteresis-synchronous, output:
.07 oz. in. @ 3,600 rpm. Globe
P/N 53A118-2.

TYPE SC. $1\frac{1}{8}$ " dia. x $1\frac{1}{2}$ "
115 v.a.c., 400 cycle, 1 phase,
hysteresis-synchronous, output:
.12 oz. in. @ 12,000 rpm. Globe
P/N 53A106-2.

TYPE MC. $1\frac{1}{4}$ " dia. x $2\frac{1}{4}$ "
115 v.a.c., 60 cycle, 1 phase,
hysteresis-synchronous, output:
.7 oz. in. @ 1,800 rpm. Globe
P/N 18A107-2 (for 3,600 rpm.,
Globe P/N 18A108-2).

TYPE FC. $1\frac{1}{8}$ " dia. x $2\frac{1}{4}$ "
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hysteresis-synchronous, output:
1.0 oz. in. @ 1,200 rpm. Globe
P/N 75A119-2 (for 3,600 rpm.,
Globe P/N 75A121-2).

GEARMOTORS

TYPE MC PLANETARY. $1\frac{1}{4}$ " dia.
x $3\frac{3}{4}$ " long. 115 v.a.c., 60 cycle,
1 phase, 6 rpm. output, 170 oz.
in., hysteresis-synchronous.
Globe P/N 33A603-600.

TYPE FC PLANETARY. $1\frac{1}{8}$ "
dia. x 3.594" long. 115 v.a.c., 60
cycle, 1 phase, 10.2 rpm., 160
oz. in., hysteresis-synchronous.
Globe P/N 83A116-352.6.

TYPE FC PLANETARY. $1\frac{1}{8}$ "
dia. x 3.190" long. 115 v.a.c., 60
cycle, 1 phase, 64.4 rpm., 20 oz.
in., hysteresis-synchronous.
Globe P/N 83A115-27.94.

BLOWERS

VAX-3-FC. 3" dia. vaneaxial for
200 v.a.c., 400 cycle, 3 phase.
120 watts, 100 cfm. air delivery
at 3.5" H₂O. Globe P/N 19A751.

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200 v.a.c., 400 cycle, 3 phase.
65 watts, 60 cfm. air delivery at
1.0" H₂O. Globe P/N 19A911.

VAX-3-GN. 3" dia. vaneaxial for
115 v.a.c., 60 cycle OR 115
v.d.c. 55 watts, 68 cfm. air de-
livery at 1.5" H₂O. Globe P/N
19A908.

D. C. MOTORS

TYPE VS. $\frac{3}{16}$ " flat x $\frac{7}{8}$ " x $1\frac{1}{4}$ "
12 v.d.c., .12 amp, 0.2 oz. in. @
8,000 rpm. Globe P/N 98A102-8.

TYPE MM. $1\frac{1}{4}$ " dia. x $2\frac{3}{4}$ "
24 v.d.c., .25 amp, 0.5 oz. in. @
17,500 rpm. Globe P/N 3A998-1.

TYPE LL. $1\frac{1}{4}$ " dia. x $2\frac{3}{4}$ "
24 v.d.c., .65 amp, 1.0 oz. in. @
11,000 rpm. Globe P/N 3A1003-1.

GLOBE INDUSTRIES, INC.

PRECISION MINIATURE MOTORS, GEARMOTORS, TIMERS,
ACTUATORS, CLUTCHES, BLOWERS, MOTORIZED DEVICES

GLOBE

This is a lightweight USS "T-1" Steel spiral case used in a hydroelectric power plant.

It looks like a giant sea shell. Water gushes through it under tremendous pressure to drive a water turbine that produces electrical power. Thirty-one spiral cases have recently been built of USS "T-1"

Steel for such famous power projects as Niagara, New York; Oahe Dam, South Dakota; Brownlee, Idaho; Noxon Rapids, Washington; and Swift, Washington. USS "T-1"

Constructional Alloy Steel is three times as strong as structural carbon steel.

Its great strength permitted almost 50% reduction in plate thicknesses and weight. Less weight means less freight. Welding costs are reduced . . . and expensive stress relieving after welding is eliminated.

If you are building rugged equipment of any kind, find out how USS "T-1" Steel can make your product stronger, lighter and more durable.

Write to United States Steel, 525 William Penn Place, Pittsburgh 30, Penna. USS and "T-1"

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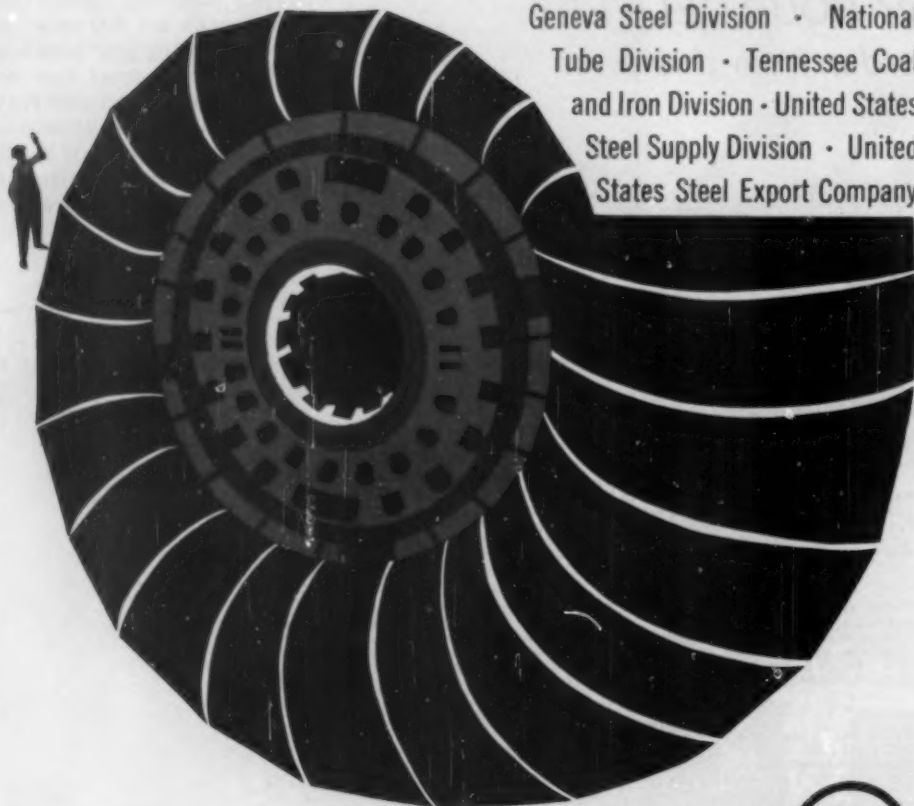
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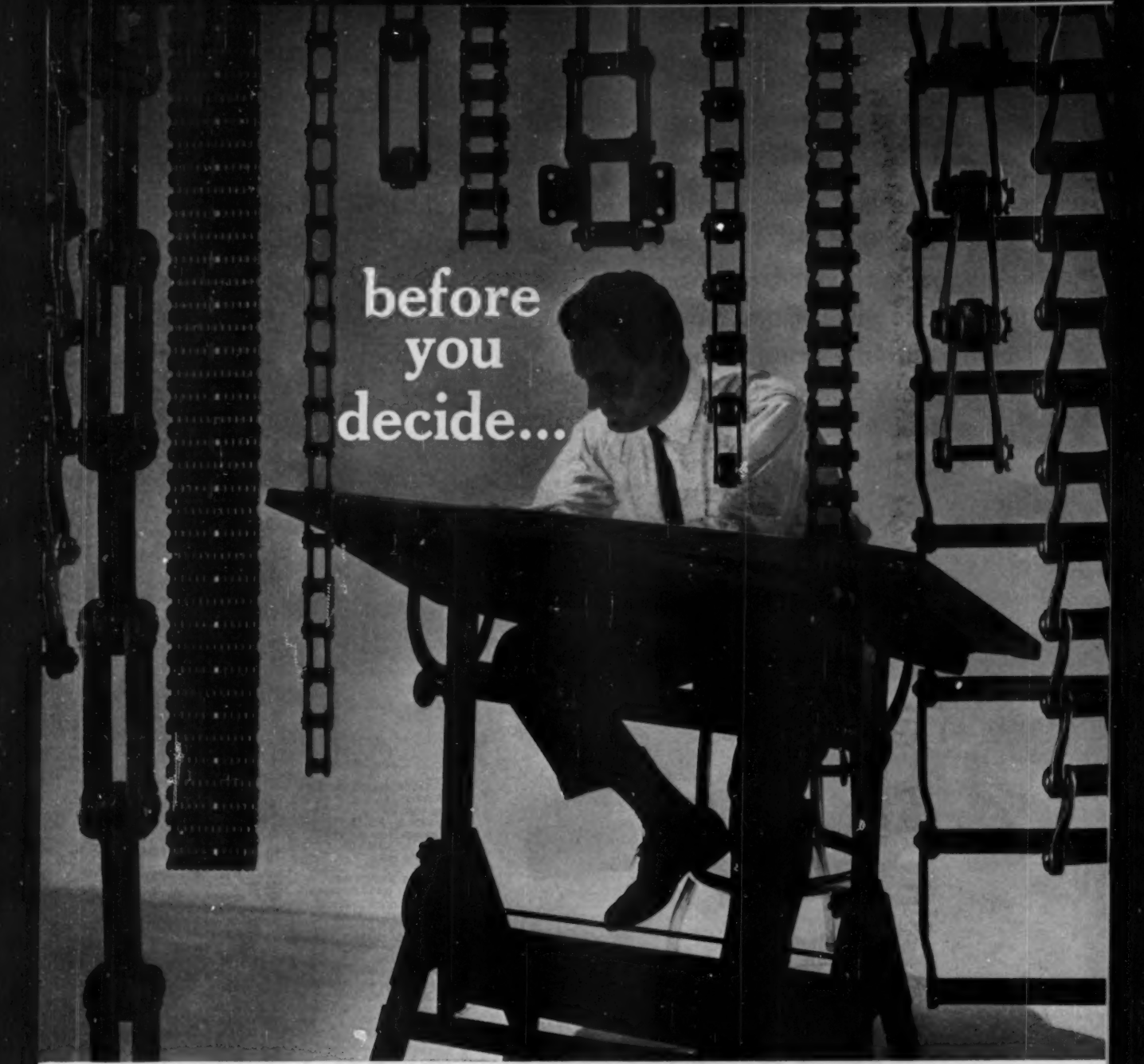
States Steel Export Company



This mark tells you a product is made of modern, dependable Steel.

United States Steel





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you
decide...

consult a chain specialist... consult Link-Belt

IT'S THE FAST, EASY WAY TO CHOOSE CHAIN. Offering you hundreds of standard chains, Link-Belt can help you choose the one chain that's precisely right for your power transmission or conveying application. Each chain is as individual as a thumbprint, with characteristics mated to specific job needs. And Link-Belt experience is at your service—to help you evaluate particular performance factors . . . to save you time in choosing the one best chain for your application (in terms of high efficiency, low total cost). Contact your nearest

Link-Belt office. Ask, too, for catalog 1050 covering the complete line of Link-Belt products and components for materials handling and power transmission.

LINK-BELT

CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1, To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World.

10-715

diversity

down to the basic American drive for a better standard of living. But, all is not so crass! This base broadening business brings *you* the products you need to set your own standards. And since designed to meet specific customer jacking up quite a few standards. sophical, let's look at the many things Hoke makes:

A business school prof might call it product diversification to broaden the marketing base, but it all boils

most of our products were demand, we've had a hand Before we get too philo-



1 FORGED NEEDLE VALVES 300 Series:

3000 psi
Brass, 303 SS, 316 SS, Monel
Aluminum 1/8" to 1/2" NPT and
with integral tube fittings

2 BAR STOCK NEEDLE VALVES 270 Series:

3000 to 5000 psi
Brass, 430F SS, 316 SS, carbon
steel, carbon steel and SS
1/4" to 1/2" NPT and with
integral tube ends

3 PRESSURE REGULATORS 680 Series (gen'l purpose):

Max. delivery press. 140 psig
Max. inlet press. 2500 psig
1/4" NPT male needle valve
outlet Std. CGA inlet

4 CHECK VALVES 570 and 580 Series:

2000, 3000, 5000 and 6000 psi
Brass, 303 SS
1/4" to 1/2" NPT and with
integral tube fittings
Ball and piston types

5 SOLENOID VALVES Series 90 (2-way type):

Series 95 (3-way type):
Differential press. ratings
to 2000 psi
Brass, 303 SS
1/4" and 1/2" NPT or JIC
tube connections
Choice of coils, housings,
corrosion-resistant trim

6 BAR STOCK NEEDLE VALVES 280 Series (metering):

3000 psi
Brass, 316 SS
1/8" and 1/4" NPT
1/16" and 1/8" orifice

7 PACKLESS VALVES 473 Series (bellows seal):

400 and 2000 psi
316 SS
1/2" NPT

8 PRESSURE REGULATORS 920 Series (ballast operated):

Max. del. press. 4500 psig
Max. inlet press. 5000 psig
1/4" NPT inlet and outlet

9 FORGED NEEDLE VALVES 100 Series:

10,000 psi (WOG)
Weldable forged carbon steel
1/8" to 1/2" NPT

10 SAMPLING CYLINDERS

Service press. 400 and 1800 psi
304 SS
1/8" to 1/2" NPT outlet
Single or double valve types
Sizes 10 ml. to 1 gallon

11 TOGGLE VALVES 490 Series (cam-closing):

1000 and 2000 psi
Brass, 303 SS
1/8" to 1/2" NPT

12 TOGGLE VALVES 450 Series (spring-closing):

200 psi
Brass, 303 SS
1/8" to 1/2" NPT and with
integral tube fittings

13 PRESSURE SWITCHES PSG-375 Series:

Operating range 15 psig to
500 psig (max. setting)
Aluminum and SS housing
Proof Press.—150% max.
operating pressure
Burst Press.—250% max.
operating pressure
1/4" NPT port or AND 10056-4,
375/2 flare

14 PACKLESS VALVES A431 Series

(brass bellows seal):
400 psi
Brass
1/8" and 1/4" NPT

SEND FOR GENERAL
CATALOG TODAY!

See our complete line at
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Hoke Incorporated
91 Piermont Road
Cresskill, New Jersey



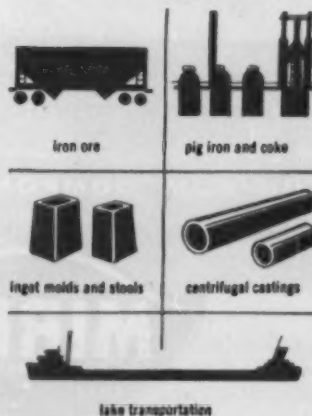
Small parts for big equipment stand up better when they are centrifugally cast by Shenango

When manufacturers of rugged, heavy-duty equipment order bushings, bearings, sleeves, seals, liners, rings or other symmetrical small parts, they quite frequently specify Shenango centrifugal castings. There is good reason for this. Precision spin-casting by Shenango always provides a dense, even grain structure which means more resistance to shock and wear. Also, since Shenango operates one of the country's largest and most modern and efficient centrifugal foundries and machine shops, large orders are filled with speed and precision. Send us your inquiry today.

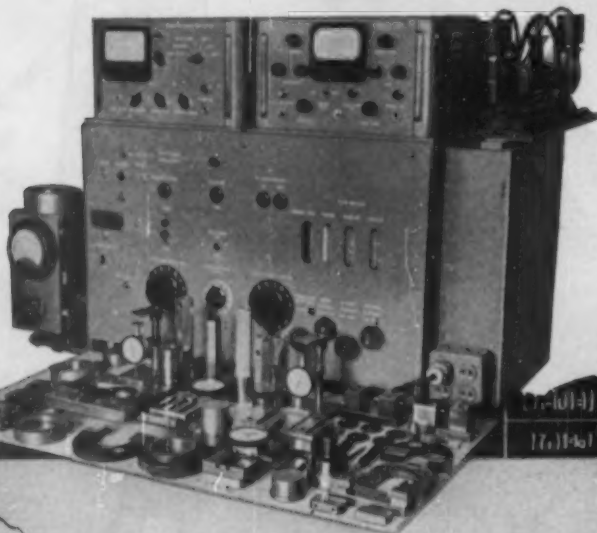
CENTRIFUGAL CASTING DIVISION
the **Shenango**
FURNACE COMPANY
DOVER, OHIO

Copper, Tin, Lead, Zinc Bronzes • Aluminum and Manganese Bronzes • Monel Metal • Ni-Resist • Meehanite Metal • Ductile Iron

THIS IS SHENANGO!



when you count on **MIRRO**
you can count on **PRECISION**



There are 46 gauges, dial indicators and pressure testing devices shown above. All of these are used to assure the maintenance of the extremely close tolerances required on *just one job*, currently being made by MIRRO.

The case in point is an assembly of seven MIRRO-made components, to be incorporated as one part of a newly designed protective unit. Its function is such that spot checking, lot sampling, or other statistical quality controls are inadequate, in this instance. Each individual unit must be tested with such severity since minute leakage at any one of the tests on the various parts would constitute failure of the assembled unit.

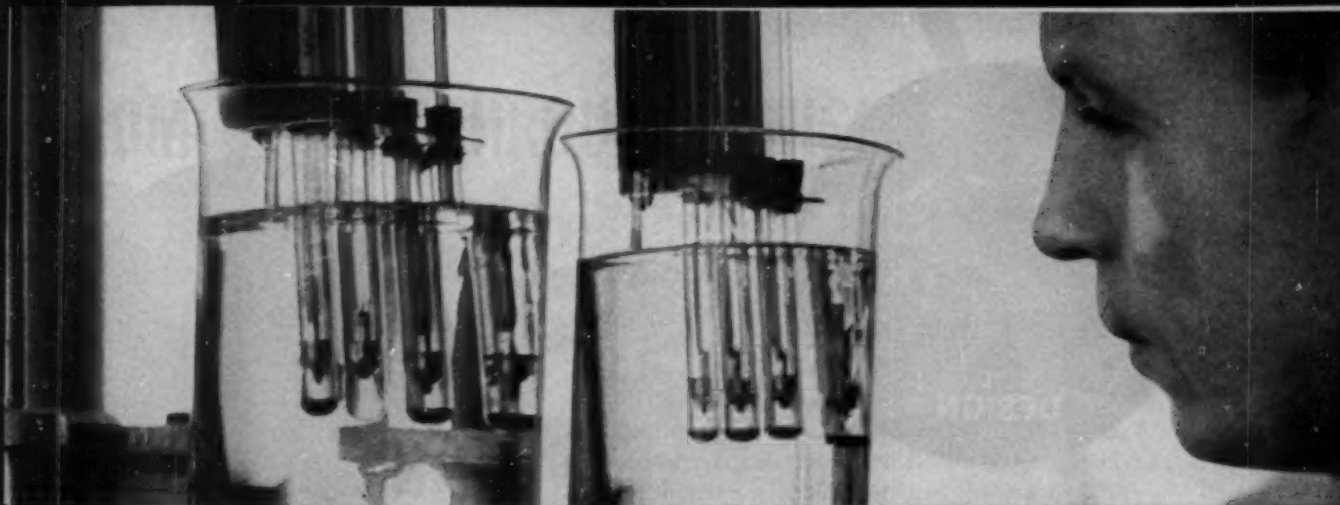
Admittedly, this is an unusually demanding contract, calling for extremely precise manufacture and assembly. We cite it as indicative of the precision-potential that you can count on, when you count on MIRRO for contract production of component parts. Regardless of the tolerances that you must maintain, we'd welcome a chance to estimate or advise.

Count on MIRRO for any production line requiring
ALUMINUM COMPONENTS
appliances, housewares, automotive, or
Government contracts.

MIRRO
THE FINEST ALUMINUM

MIRRO ALUMINUM COMPANY, MANITOWOC, WISCONSIN

Fifth Avenue Bldg., New York 10
Merchandise Mart, Chicago 54



Dropping point test shows how greases react to heat. Beaker fluid has been heated to 390°F. All greases tested except Darina (second tube from left) have passed from solid to liquid state.

BULLETIN:

Shell reveals the remarkable new component in Darina Grease that helps it save up to 35% on grease and labor costs

Darina® Grease is made with Microgel*, the new thickening agent developed by Shell Research.

Darina lubricates effectively at temperatures 100° hotter than most conventional soap base greases can withstand.

Read how this new multi-purpose industrial grease can help solve your lubricating problems and even save you up to 35% on grease and labor costs.

THERE IS NO soap in Darina Grease. No soap to melt away—wash away—or dissolve away.

Instead of soap, Darina uses Microgel—a grease component developed by Shell Research.

What Microgel does

Because of Microgel, Darina has no melting point. It won't run out of gears or bearings.

Compared with most conventional soap-base greases, Darina provides significantly greater protection under adverse service conditions.

Mix water into Darina and the

grease does not soften. It shrugs off water—won't emulsify.

Resists heat

Darina will withstand operating temperatures 100° hotter than most conventional multi-purpose greases. It cuts leakage and reduces the need for special high-temperature greases.

Also, Darina resists slumping, thus forming a more effective seal against foreign matter.

Saves money

Shell Darina can reduce maintenance expenses while it protects your machin-

ery. Savings of up to 35% on grease and labor are quite possible.

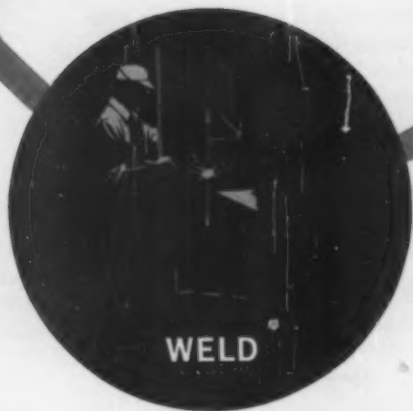
In some cases lubrication intervals have been extended to double what they were before. Less grease is consumed and less time consumed applying it.

For details, see your Shell Representative. Or write: Shell Oil Company, 50 West 50th Street, New York 20, New York.

*Registered Trademark



A BULLETIN FROM SHELL
—where 1,997 scientists are helping to provide better products for industry



Strong
Modern
Dependable

FROM DESIGN THROUGH FINISHED PRODUCT

Republic saves you money on sheet metal fabrication, every step of the way



A skilled design and engineering staff . . . complete production facilities that include modern assembly lines for shearing, punching, forming, welding, Bonderizing, painting, and packaging . . . diversified experience and problem solving know-how backed by over 50 years of specialization in sheet metal fabricating . . . these are key reasons why Republic's Berger Division can save money, produce a better quality product, meet delivery schedules, *for you*.

A tour of Berger's efficient plant points up another factor that keeps costs at rock bottom. Scientifically planned material flow is combined with straight-through production lines to eliminate excessive handling, speed fabrication, assembly, and delivery.

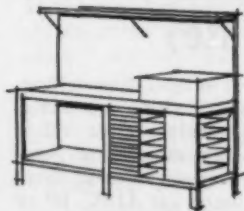
Most important, you can put this \$5,000,000 fabricating facility to work for you without investing a dime . . . to make cabinets, housings, and components for the products you now produce, or to make new items that will round out your line. For complete details, price quotations, and delivery information, contact Berger's Contract Manufacturing Department today, or mail the coupon below.



REPUBLIC STEEL

REPUBLIC HAS THE FEEL FOR MODERN STEEL

Circle 241 on Page 19



Typical products, fabricated for Berger customers from cold rolled carbon, galvanized, and stainless steels, Electro Paint-lak®, and vinyl coated sheets.

REPUBLIC STEEL CORPORATION
BERGER DIVISION, DEPT. A-2350
1044 BELDEN AVE., CANTON 5, OHIO

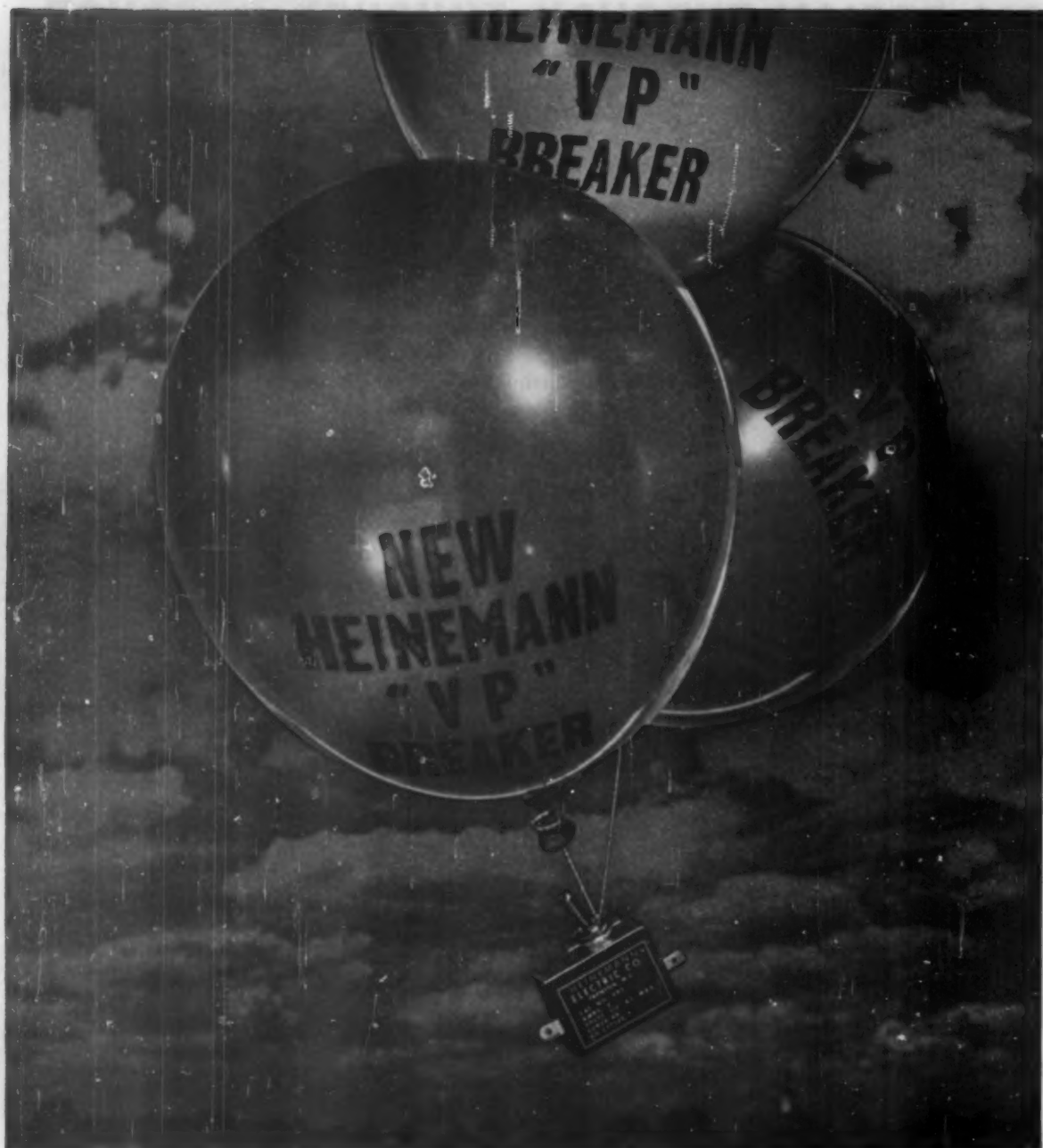
Send more information on:
☐ Contract Facilities

Name _____ Title _____

Company _____

Address _____

City _____ Zone _____ State _____



Only 1-1/2 ounces (including the switch plate)

Heinemann's new Series VP may well be the lightest circuit breaker made. For sure, it's one of the smallest and most compact you'll find around. Yet, remarkably, it's capable of handling all the functions of much larger Heinemann breakers.

It is temperature-stable. Current rating and calibrated trip-points are completely unaffected by ambient

temperature. No derating . . . ever.

It is available with a choice of time relays. You can have either a "fast" or "slow" delay. Or instantaneous response.

It can be furnished with any of Heinemann's special-function internal circuits. With a little ingenuity and a special circuit, you can make the breaker do such out-of-the-

ordinary chores as remote switching, circuit "slaving," alarm signaling.

The matchbox-size Series VP is available in any integral or fractional rating you might need, from 0.050 to 15 amps (at 110V, 60 or 400 cycles AC, or 50V DC).

Bulletin VP will give you detailed specifications and dimensions. A copy is yours for the asking.

HEINEMANN ELECTRIC COMPANY  **172 BRUNSWICK PIKE, TRENTON 2, N. J.**

EA 2480



One in a series of technical reports by Bower

BEARING BRIEFINGS

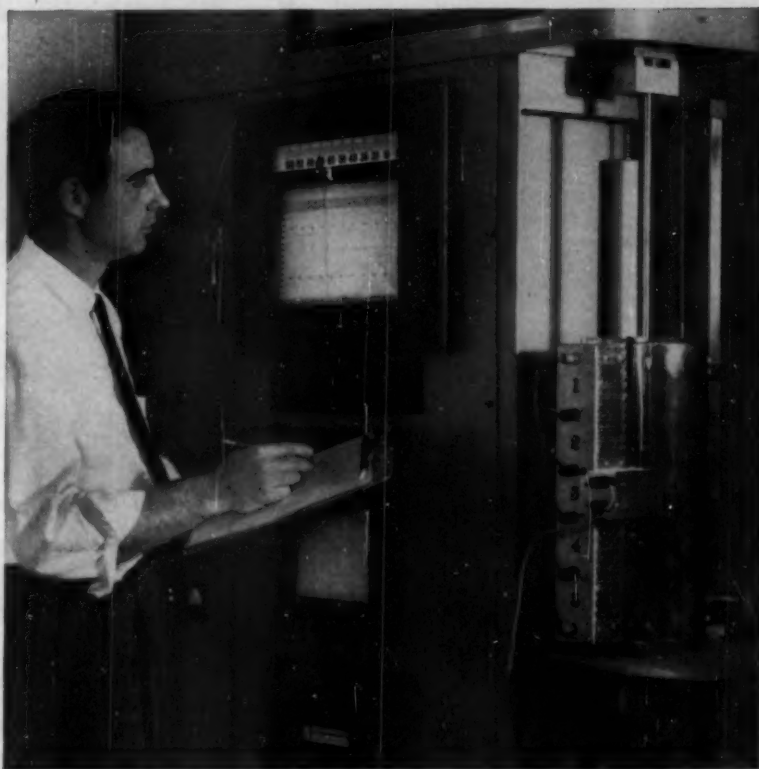
TESTING PUTS THE HEAT ON—HELPS BEARINGS BEHAVE IN EXTREME ENVIRONMENTS

In industry today, bearing operating conditions are becoming increasingly severe. To conquer difficult environments, heat, corrosion and oxidation, Bower conducts exhaustive research to achieve improved bearing performance. One important area of Bower research, for example, is the development of special alloys to withstand extreme heat. To do this, Bower researchers use special heating apparatus to study hardness, strength and other characteristics of alloys at temperatures in excess of 1000°F.

One of the devices Bower utilizes to assure bearing precision at high temperatures is a creep tester. Bower engineers use it to load a test bar to a predetermined stress level, then, with the assistance of a special heating unit, find out precisely how much the bar stretches as temperatures are elevated to a thousand degrees F., and beyond.

With this type of data and the help of other Bower precision research equipment, engineers can determine alloys that best withstand torrid temperatures. They can also effectively mate thermal expansion characteristics of the various alloys used in roller bearing components and in shafts and housings as well. As a result of this mating, Bower creates bearings that maintain precision in the required temperature ranges and ensures bearings that provide long life, heavy load capacity and high-speed operation.

Because of Bower's continuing research



Bower engineers study how alloys stretch as temperatures rise in excess of 1000°F., to perfect bearings that can take it.

in bearing alloys and other critical areas, we suggest you consider Bower to assist you with your bearing needs. Bower provides a full range of types and sizes

in tapered and cylindrical roller bearings as well as in journal roller assemblies. Bower Roller Bearing Division, Detroit 14, Michigan.

BOWER
ROLLER BEARINGS

tapered
cylindrical
journal

DIVISION OF
FEDERAL-MOGUL-BOWER
BEARINGS, INC.

MARLIN-ROCKWELL
RELIABILITY
COUNTS in EXCITING NEW FIELDS
of Leadership



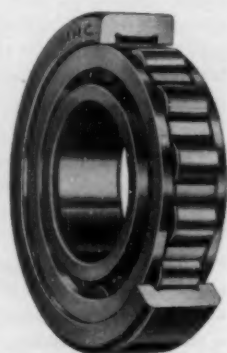
THE WORLD'S FIRST OPEN-OCEAN HYDROFOIL CRAFT



Hull designed and built by Grumman and its affiliate, Dynamic Developments, Inc.

MRC Bearings have been selected for use in the power plants, intermediate power transmissions and propeller shafts to provide maximum reliability.

MRC Maximum Capacity Duplex Bearings with multiple rows, mounted in tandem, give ultimate thrust load capacity for any available space.



Backed by 63 Years Experience

Consult OUR Engineering Department on YOUR Bearing Problems

MARLIN-ROCKWELL CORPORATION

Executive Offices: Jamestown, N. Y.



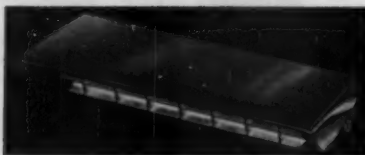
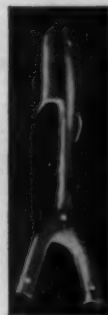
SPECIFY TENZALOY FOR:

**BRILLIANT FINISH AND SHARP DETAIL
IN HIGH STRENGTH CASTINGS**

Tenzaloy aluminum castings take a brilliant polish, anodize clear white and can be dyed in a wide range of decorative colors. Tenzaloy casts easily for sharp detail and complex shapes. Its great strength in thin cross section makes possible an extremely wide variety of products combining beauty and utility.

Special techniques are not required for handling this high grade alloy in the foundry... and it needs no heat treatment. Tenzaloy ages at room temperature to provide full-strength castings with mechanical properties equivalent to heat-treated alloys. Tenzaloy also has unusual dimensional stability, exceptional machinability, high impact and shock resistance, high yield and tensile strength, and excellent corrosion resistance.

Tenzaloy's unique inherent properties offer wide, new latitude to designers and manufacturers. For your copy of Bulletin 103R5, "Tenzaloy, the Self-Aging Aluminum Casting Alloy," write today to: Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.



TENZALOY

GRAPHITAR[®]

(CARBON-GRAPHITE)

FOR DEPENDABILITY

GRAPHITAR'S own character makes it dependable. A non-metallic engineering material, formed from carbon and graphite powders and a special binder, compacted under high pressures and furnace at temperatures up to 4,500°F., GRAPHITAR possesses inherent characteristics that give finished parts exceptional dependability. GRAPHITAR'S natural heat resistance, for example, gives bearings, seals, vanes and rings exceptional dependability whenever dependability is one of the prime requisites.

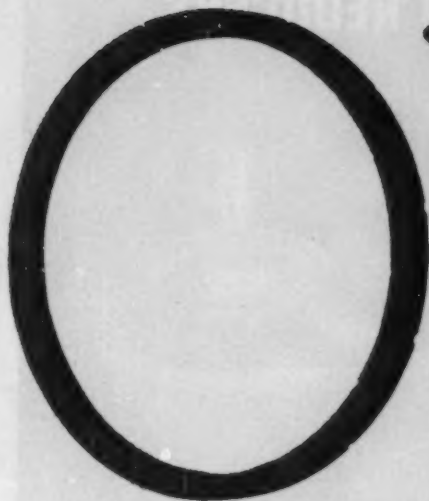
There are other characteristics every bit as important to GRAPHITAR'S dependability. They include chemical and magnetic inertness, mechanical strength and adaptability to self-lubrication. Besides these natural characteristics, GRAPHITAR engineers can control porosity, strength and hardness to match GRAPHITAR'S physical properties to each individual application. It's little wonder that GRAPHITAR has become one of the design engineer's most versatile and useful materials.

In this laboratory test stand, oxidation-resistant GRAPHITAR parts are being checked under simulated operating conditions. Similar tests have proven that, when GRAPHITAR parts are exposed in oxidizing atmospheres at 1,200°F., they show only a weight loss of less than six percent after 200 hours.

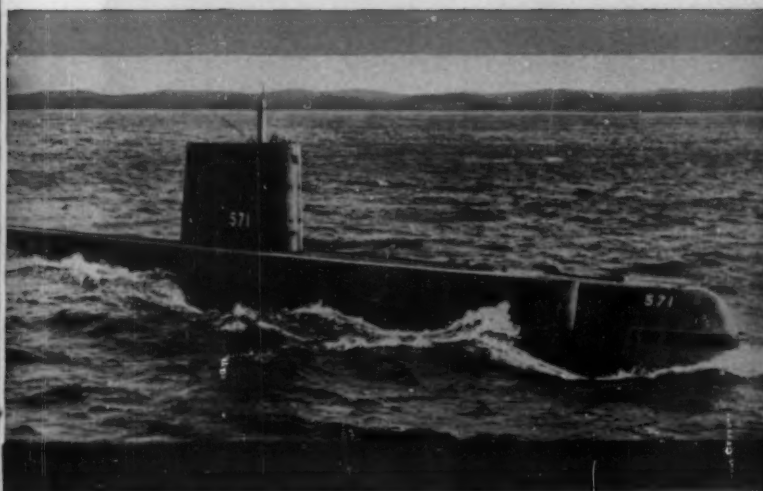


With the aid of photomicrographs, engineers at The United States Graphite Company gain valuable information about the microstructure of GRAPHITAR parts. Modern laboratory equipment such as the Metallograph enables engineering personnel to advance product quality for maximum dependability. Extensive and continuing R&D work has always been an integral part of The United States Graphite Company's operations.





GRAPHITAR air/oil seals employed in today's high-speed turbojet engines have established an enviable record for operating dependability. Installed on the main shaft of the turbine, GRAPHITAR seals successfully withstand tremendous shaft speeds and generated heat.



GRAPHITAR bearings in the power reactor pumps of American nuclear submarines have compiled an outstanding record for dependability.



Unusually shaped parts of GRAPHITAR can be molded easily with today's modern techniques. Ears, face slots and outside diameter notches of friction disc above, left, were molded in one operation without need for secondary machining and finishing.

Do you have an application in which GRAPHITAR'S dependability can help solve a tough problem, reduce your costs and improve the operational life of your products? Our engineering staff can help you find out. Our field men can also give specialized, on-the-job consultation. Send for your free copy of Engineering Bulletin #20. Included is helpful information about the properties, characteristics and applications of GRAPHITAR.



THE UNITED STATES GRAPHITE COMPANY



DIVISION OF THE WICKES CORPORATION, SAGINAW 7, MICHIGAN
GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

Circle 246 on Page 19

B-294-36

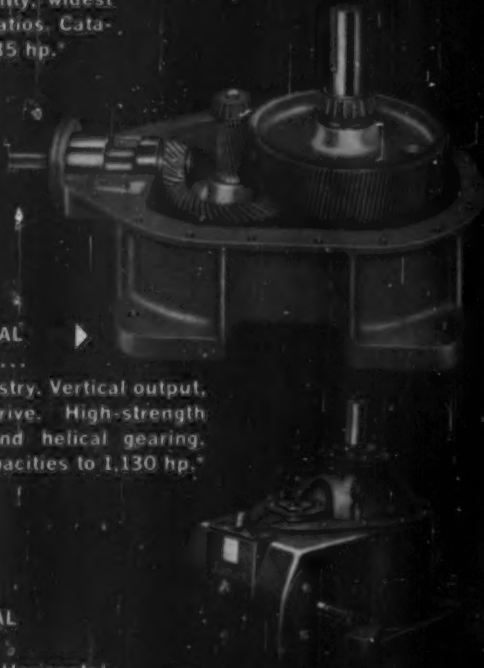
From the broad H-R line: JONES HEAVY-DUTY SPEED REDUCERS



◀ **JONES BALANCED-DESIGN
HERRINGBONE** ...
Ruggedness and reliability, widest
selection of sizes and ratios. Cata-
logued capacities to 2,135 hp.*
Bulletin J-26.



▶ **JONES VERTICAL
SPIRAL BEVEL** ...
Newest in industry. Vertical output,
right angle drive. High-strength
spiral bevel and helical gearing.
Catalogued capacities to 1,130 hp.*
Bulletin J-25.



▲ **JONES WORM HELICAL** ...
Economical heavy duty service, ver-
tical drive, medium to high speed
reduction ratios. Catalogued capaci-
ties to 175 hp.* Bulletin J-14.

◀ **JONES HORIZONTAL
SPIRAL BEVEL** ...
Most-up-to-date design. Horizontal
output, right angle drive, high-
strength spiral bevel and helical
gearing. Catalogued capacities to
1,130 hp.* Bulletin J-25.

*Higher capacities available on special order.

Let your H-R power transmission specialist help you ... select the ratio, capacity, and design of heavy-duty speed reducers closest to your needs ... directly from H-R standard equipment ... and at "off-the-shelf" savings. Name your toughest service. Dust and grit ... shock loads ... corrosive atmosphere ... extreme tempera-

tures ... torsional vibration ... pulsation ... Jones Machinery has been solving these problems for 70 years. There is a team of H-R power transmission specialists in your area, backed by one of industry's most comprehensive lines, ready to put this dependability to work for you. Give your nearest Hewitt-Robins sales office a call.

WRITE FOR H-R POWER TRANSMISSION BULLETINS


JONES speed reducers: herringbone, J-26; spiral bevel, J-25; worm helical, J-14; shaft-mounted, J-19; in-line helical, J-18; gearmotors, J-17; power transmission components, J-10A, J-16, J-23; complete drive units, J-11, J-22; UNION CHAIN: roller chain, RT-60; drive and conveying chain, A-4.

HEWITT-ROBINS, DEPT. 11-61, STAMFORD, CONNECTICUT



HEWITT-ROBINS

Conveyor Machinery and Belting • Power Transmission
Hose • Vibrating Equipment • Engineering Services



300% UPSET



... crucial cold heading done with KEYSTONE WIRE

To upset an indented hex washer head sheet metal screw with a thin washer 300% larger than the original wire diameter calls for good tooling and superior quality wire. Such a screw is cold headed on a 2-blow header by Midland Screw Corporation, Chicago, Ill., from Keystone Special Process Wire.

Ed Wick, Customer Service Coordinator, has exceptional praise for Keystone Wire. He says, "In cold heading this sheet metal screw we have had our best success with Keystone C-1018 Special Process Wire. We like to work with this wire. A big factor in its selection is the uniform quality throughout the coil, correct thermal treatment and flowability characteristics—as well as excellent service and dependable deliveries from Keystone Steel & Wire Company."

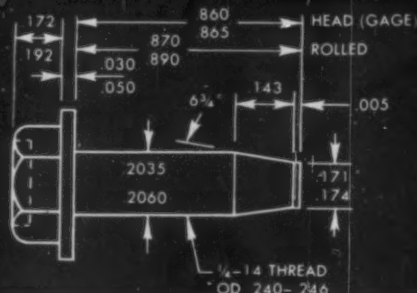
If you are looking for a high quality wire with delivery you can rely upon, it will pay you to investigate Keystone Special Process Wire.

Keystone Steel & Wire Company, Peoria, Illinois



KEYSTONE

WIRE FOR INDUSTRY
MADE AT PEORIA, ILLINOIS, U.S.A.



BETTER PERFORMANCE



on the tough jobs

Madison-Kipp zinc and aluminum die castings

These five castings assembled in the order that you see them are engineered for a radial arm saw. Intricate in design, they must match perfectly and that means extremely close tolerances. Mass production demands a minimum of secondary operations.

This is just one example of the wide range of castings that Madison-Kipp is called upon to engineer

and produce—in quantity. All, however, have one thing in common—the need of a dependable source with years of seasoned experience in producing die castings.

We have a 24-page book showing some of the die casting problems we have solved, and containing information on other Madison-Kipp products. A copy is yours for the asking. Write for one.



kipp

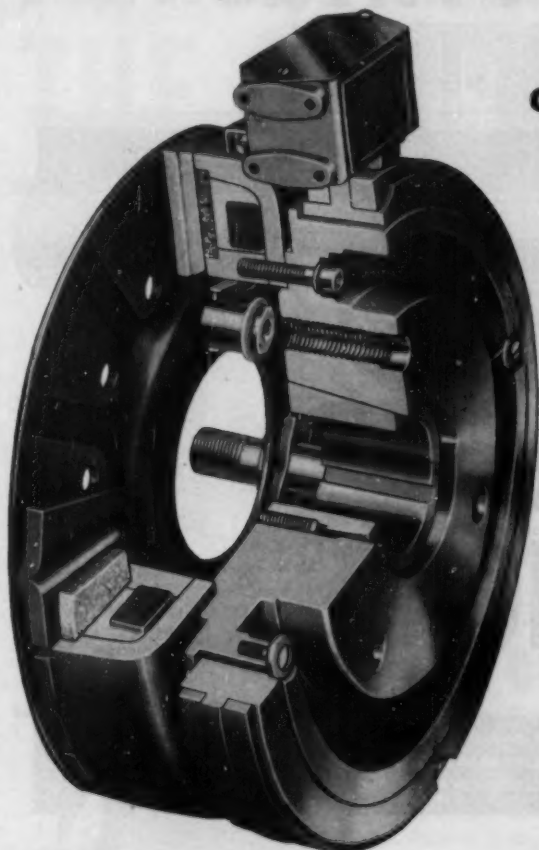
MADISON-KIPP CORPORATION

210 Waubesa Street • Madison 10, Wisconsin, U.S.A.

Skilled in Die Casting Mechanics • Experienced in Lubrication Engineering • Originators of Really High-Speed Air Tools

EATON DYNA-TORQ[®]

MAGNETIC-FRICTION CLUTCHES and BRAKES



The Ideal Solution to Exacting Clutching and Braking Problems

These highly responsive, trouble-free units provide accurate control of intricate automatic machinery. Operating on 6, 12, 24 or 90 V.D.C., Dyna-torQ units may be actuated by micro-switches, photo-electric cells, relays or any "ON-OFF" signal to perform a wide range of functions in processing and fabricating applications. The compact rectifier type control converts AC power to DC power and may be remotely mounted out of busy machine areas.

Eaton Dyna-torQ Clutches and Brakes are available from 1 $\frac{3}{4}$ " through 15" in diameter. They may be easily and quickly installed on either new or existing plant equipment. Exclusive features of design and construction mean worthwhile savings.

HP @ 1800 R.P.M. (Typical Application)

MODEL	HP	MODEL	HP
302	1/20	308	7 $\frac{1}{2}$
303	$\frac{1}{8}$	310	10
304	1	312	20
305	2	315	25

Dyna-torQ Distributors in many principal cities carry Dyna-torQ Clutches and Brakes in stock for immediate delivery.



ACCURATE POWER CONTROL

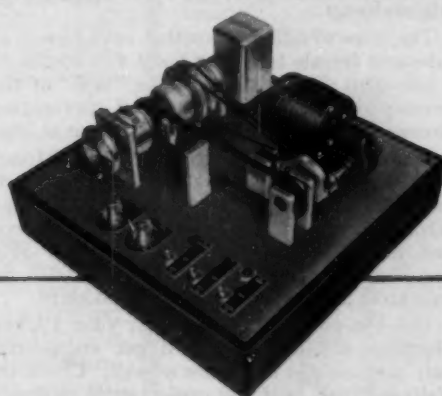
DEPENDABLE MOTION CONTROL

RAPID RESPONSE • LOW MAINTENANCE COST

EASY BUILT-IN INSTALLATION

WIDE RANGE OF SIZES AND CAPACITIES

Send for Illustrated Literature.

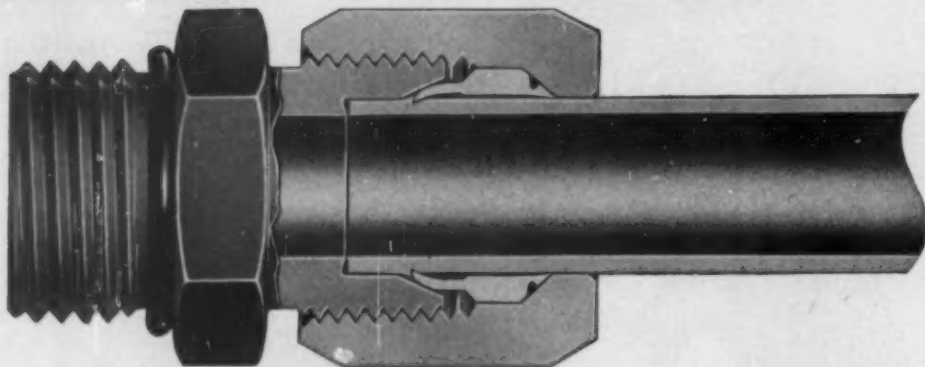


Ask your Dyna-torQ Distributor to demonstrate Dyna-torQ in action and see for yourself the many possible applications for Dyna-torQ in Motion Control and Power Transmission.

EATON

— DYNAMATIC DIVISION —
MANUFACTURING COMPANY
3122 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

ONLY PARKER "FERULOK"[®] FLARELESS FITTINGS



GIVE YOU DOUBLE SEALING ACTION

Built for heavy duty but ideal for standard tubing as well, Ferulok's visible bite means a safe, leak-proof connection which will hold well beyond tube bursting pressures. You can see this bite, inspect it . . . and *know* that you have safe make-up.

The same wedging action that seals ferrule to tube and ferrule to fitting body also results in a firm grip on the tube by the "heel" of the ferrule, damping vibration and preventing stresses from concentrating at the line of bite.

Made in steel, stainless steel and Monel, Ferulok meets, and actually exceeds, the performance standards set by S.A.E., J.I.C., and A.S.M.E. It also has Underwriters' Approval and meets federal specification MIL-F-5506 and BuShips specification MIL-F-21467 for hydraulic and air systems in Naval ships.

Get the complete story from your Parker-Hannifin distributor. You'll get engineering help and prompt deliveries as well. Check the Yellow Pages, or if you prefer, write us direct.

Self-centering action
assures even bite around
circumference of tube:

... WITH THE VISIBLE BITE



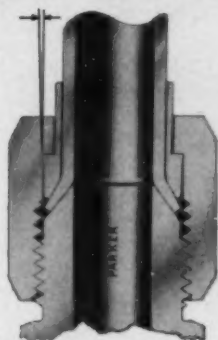
PARKER-HANNIFIN

Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio
PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS

8000-PM

EUROPEAN DIVISION • PARKER-HANNIFIN N.V. • SCHIPHOL • THE NETHERLANDS

PARKER "TRIPLE-LOK"® 37° FLARE FITTINGS GIVE YOU THE QUALITY YOU NEED



A tiny Reverse Clearance Angle makes the Parker sleeve act as a lockwasher. Sleeve shoulder exerts pressure back against nut to prevent loosening from vibration, or from expansion and contraction.

Fittings shapes are machined from high-strength, one-piece forgings. No cast, extruded or brazed construction. The finer grain structure of forgings provides higher tensile strength and a greater elongation factor.

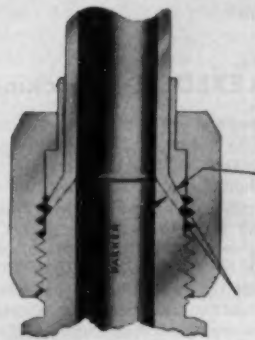


AT EVERY CRITICAL POINT!!!

PARKER WORKMANSHIP PAYS OFF FOR YOU IN ASSEMBLY AND USE

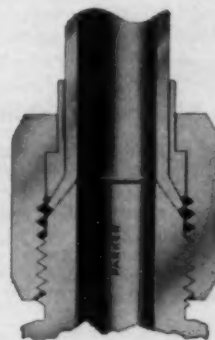
The fact that Parker developed the original 37° flare fitting is only part of the story. At Parker today, infinite attention to detail is your assurance that you will get all the plus values inherent in the original Parker design.

Illustrated here are only four of the many critical points which Parker watches in making "Triple-lok," the 37° flare fittings that bear the Parker name. Tiny variations from the angles and clearances to which Parker craftsmen work can mean the difference between the maximum protection you get from the Parker product and something much less dependable. A Parker-Hannifin distributor is as near you as your telephone. Check the Yellow Pages, or write us direct.



The precise Differential Angle between sleeve and nose gives you perfect surface contact, maximum sealing and even distribution of make-up loads. It compensates for natural thinning of the flare.

"Triple-lok" parts can be used repeatedly . . . are never deformed in make-up nor wedged on to tubing. Sleeve never rotates during assembly . . . no danger of wiping or scoring tube flare.



PARKER-HANNIFIN

Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio

PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS

EUROPEAN DIVISION • PARKER-HANNIFIN N.V. • SCHIPHOL • THE NETHERLANDS

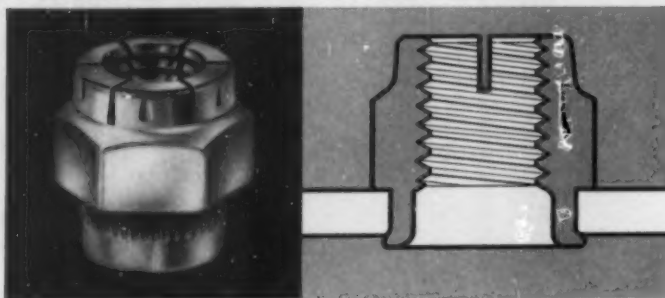
3 quick ways to put load-bearing threads in thin material... permanently!

These SPS 160,000 psi clinch and swage nuts are designed expressly to provide one-piece, all-metal thread wells in thin-section materials of .020 inches and more. Installed with one pressure stroke, they become a permanent, vibration-proof part of your product. No more loose nuts to handle; no need to hold nuts with a wrench while tightening screws. Result: faster, more economical assembly, particularly where it would be awkward to position and hold ordinary nuts. And these same benefits apply to later disassembly and reassembly in the field.

FLEXLOC Self-Locking Clinch Nuts

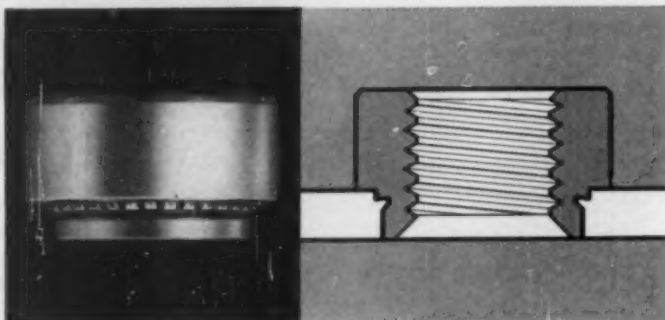
Designed for thin-section materials up to Rockwell C20 hardness. Incorporating the time-proven FLEXLOC self-locking feature, they are specially valuable where equipment must be disassembled periodically. Installed by roll-over clinch method with SPS punch and dolly tips.* Sizes #4 through $\frac{3}{16}$ inch in cadmium-plated steel (serviceable to 550°F), stainless steel (to 800°F), brass and aluminum (to 250°F). Also microsizes—#0 to #4—in same materials. Locking torque and vibration requirements meet or exceed MIL-N-25027.

*Recommended installation tools available as standard products. Dolly tips for flush mounted clinch nuts also available.



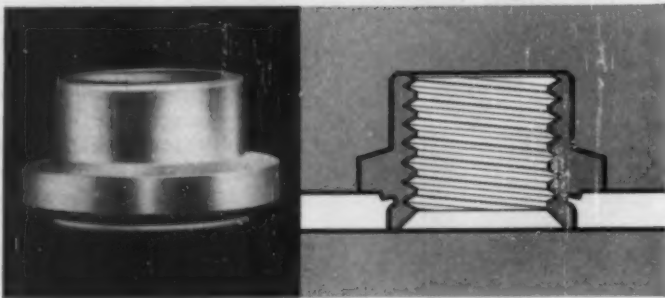
SPS Swage Nuts

The simple, economical solution to the problem of getting sufficient load-bearing threads in thin material. Installed from one side, they mount flush—without use of special tools and without distortion or discoloration of parts. Suitable for materials to Rockwell C25 (this includes mild steels). Good torque-out and push-out values assured by positive displacement of metal into retaining groove. Sizes #2 through $\frac{1}{2}$ inch in cadmium-plated steel. Serviceable to 550°F.



SPS Self-Locking Swage Nuts

Provide flush mounted, self-locking thread element which combines excellent performance with light weight. Installed from one side—with SPS dolly tip—in materials up to Rockwell C27. Push-out and torque-out values, as well as locking torque and vibration requirements, meet or exceed MIL-N-25027. Sizes #2 through $\frac{1}{2}$ inch in cadmium-plated steel. Serviceable to 550°F.



SPS

where reliability replaces probability

SPS alone offers you this range of one-piece nuts designed specifically for fastening in thin-section materials. And SPS offers them from stock—available for fast delivery through your SPS distributor. Individual bulletins are available on each of these special-purpose SPS nuts—Bulletins #2275 (clinch nuts), #2447 (swage nuts), #2701 (self-locking swage nuts). For copies, write Standard Pressed Steel Co., INDUSTRIAL FASTENER DIVISION, SPS, JENKINTOWN 18, PENNSYLVANIA.



Five-gallon standard solution bottle and gallon jug with handle are examples of laboratory ware blow-molded by The Nalge Co., Inc., Rochester, N.Y.

they're better
...cost less
blow-molded of
AVISUN
polypropylene

From laboratory ware to picnic jug liners, AviSun polypropylene is finding many applications in fields long limited to glass.

1 HIGH HEAT RESISTANCE. Polypropylene blow-molded containers can be repeatedly sterilized with boiling water or autoclaved with live steam.

2 TOUGHNESS. Strongest and lightest of all thermoplastics, polypropylene bottles survive drops and hard knocks without cracking or shattering. Lightweight polypropylene vessels are easier to handle, unlikely to slip when wet. Threads for caps aren't damaged by overtightening.

3 CHEMICAL RESISTANCE. Polypropylene is ideal for holding liquids. It is inert, doesn't absorb liquids, resists stains and is unaffected by most reagents. F.D.A. approved.

4 ECONOMY. Lightweight, low-cost polypropylene is readily blow-molded, gives more bottles per pound of resin, lower packaging and shipping costs, for true economy in the final product.

The same advantages that make polypropylene valuable for these large containers can work for you in your product. Call on AviSun for complete polypropylene specifications and expert technical assistance.



* a trademark of AviSun Corp.

In Canada: Courtaulds Plastics Canada, Ltd.

AVISUN CORPORATION
Dept. 581 1345 Chestnut St.
Philadelphia 7, Pa.

Please send full information on blow-molding grades of AviSun polypropylene.

NAME _____
(Please Print)

COMPANY _____

ADDRESS _____

CITY _____ STATE _____

NAT'S
quick facts
about
Fasteners...



Shining example...of big things in specials by National

This is a large offset eyebolt, shown here big as life. We designed and made it to order for one of our customers.

To begin with, it shows that we can and do make some sizable things in the way of cold headed Special Products.

But there's more here than seems to meet the eye.

When our customer brought us this eyebolt, he had been having it made as a forged eye welded to a machined bolt, with a cut thread.

We gave it some thought, then made it... with a difference. We cold formed it in one piece, and rolled the thread... turning out a stronger, more practical, and more efficient part, and lopping off costs all along the line.

And there's the real point... what we

really mean when we mention doing BIG things in Specials, at National... better parts, large or small, at lower cost, by cold heading and designing for profit.

We do it right along, and we can very likely do it for you, too. Want to find out? Just drop a note to Special Products Service, at our address*. And if you just happen to have a Special problem, tell us all about it—and let us help.

*It will bring you this illustrated booklet "Bring your Special Problems to National", 16 pages about Specials as National sees them.



The National Screw & Mfg. Company • Cleveland 4, Ohio

California Division, The National Screw & Mfg. Company • 3423 South Garfield Avenue, Los Angeles 22, California



A Metal Problem...With Complications

The hour is late...the girl impatient...and a rough metal problem has to be solved *tonight*. Pressure that breeds ulcers. Pressure that might not exist if this harried engineer had up-to-date information on HAYNES alloys.

HAYNES alloys solve tough metal service problems—severe abrasion...metal-to-metal wear...corrosion...difficult or impossible lubrication...high temperatures. They are available in any shape, any quantity, any size. As finished parts...ready to use...or as rough castings, forgings, bar stock, sheet, plate, or wire.

Our 32-page properties booklet details the characteristics of 15 HAYNES alloys. Send for it. Our engineers are at your service, too.

Address Inquiries to Haynes Stellite Company, 270 Park Avenue, New York 17, New York

Circle 256 on Page 19

HAYNES

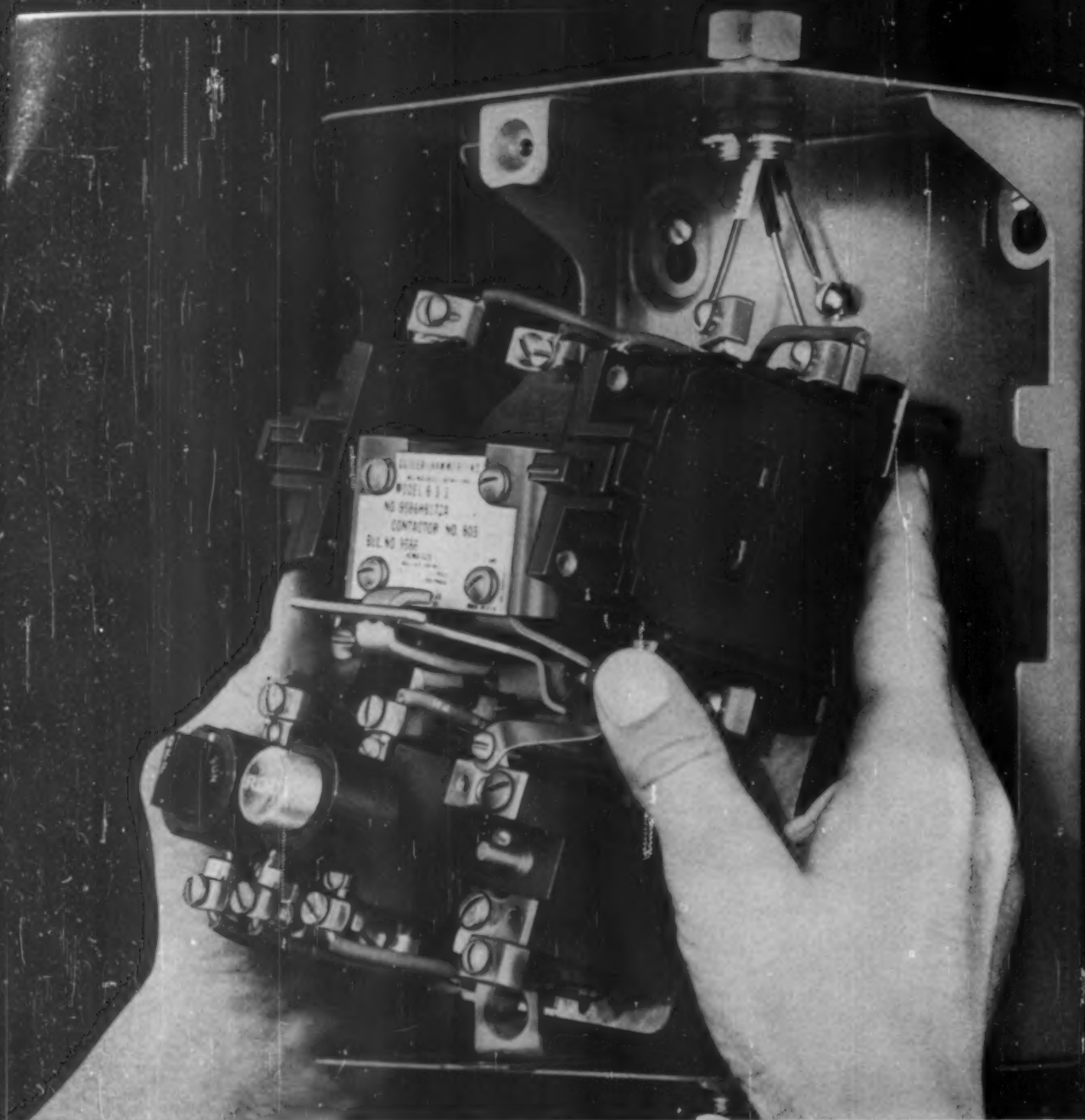
ALLOYS

HAYNES STELLITE COMPANY

Division of
Union Carbide Corporation,
Kokomo, Indiana



The terms "Haynes" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.



CUTLER-HAMMER QUALITY 3-STAR MOTOR STARTERS AVAILABLE IN 10 SIZES, 00 THROUGH 8





CUTLER-HAMMER MOTOR STARTERS

Still the proven standard of quality...always in stock for immediate delivery

Millions of satisfactory operations in thousands of applications have proved the unmatched quality of Cutler-Hammer across-the-line magnetic starters. That this line is still recognized as the leader—nine years after the original design was developed—is a great tribute to the years-ahead thinking of Cutler-Hammer engineers.

FIRST IN '53—STILL THE LEADER IN '61

Since the Three Star line was introduced in 1953, many improvements have been made; magnet coils that far exceed NEMA standards, for example. But many achievements of the original design—vertical, dust-free contacts; overload relays adjustable to within 3% of actual full-motor ratings; provision for 2 or 3-coil overload relays in the same enclosure—are features no other manufacturer has been able to improve. You can safely bet that when these pace-setting features are improved, it'll be another Cutler-Hammer development.

ALWAYS AVAILABLE FOR FAST DELIVERY

You'll find the smaller sizes of Cutler-Hammer Starters always in stock at your local distributors—larger sizes immediately available from the factory. We hope you'll make your own feature-by-feature comparison between the Cutler-Hammer line and any other starter on the market. Look especially carefully at such vital advantages as ease of installation, high interrupting capacity, coil construction and accessibility.

Regardless of what features you select as the criterion of superiority, we're sure you'll choose Cutler-Hammer after you've made your unbiased comparison.

If you're one of many companies being forced to stock two sets of parts because of design changes, now is an excellent time to standardize on Cutler-Hammer.

Call your distributor or local Cutler-Hammer Sales Office soon. Or write for Publication LO-70-W243.

WHAT'S NEW? ASK..

CUTLER-HAMMER

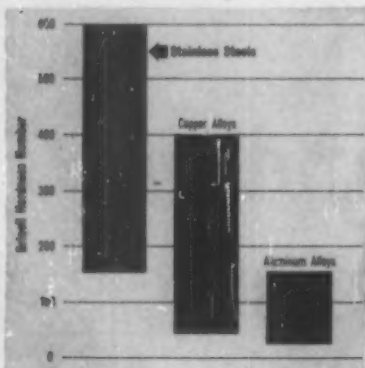
Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Cutler-Hammer Canada, Ltd.; Cutler-Hammer Mexicana, S. A.



stainless steels give design engineers a wider application range

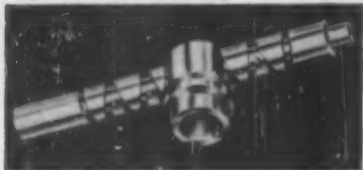
In your constant search for materials that serve a wide range of design applications, investigate the performance characteristics of Carpenter Stainless Steels. The following data highlight several important reasons why these versatile steels continually deliver bonus benefits to both design engineers and manufacturers.

Greater hardness range



Only stainless steels can give you the combination of good corrosion resistance with sufficient range of hardness to meet any of your requirements. For example, fully annealed 18% Cr-8% Ni stainless steels such as Carpenter Stainless No. 4-A (Type 304) have a Brinell hardness of about 150, whereas heat treated Carpenter Stainless No. 440-C (Type 440C) can be as hard as 600 Brinell and both materials offer excellent resistance to a wide variety of corrosive environments. The range of hardnesses available with either copper-base or aluminum-base alloys is much smaller.

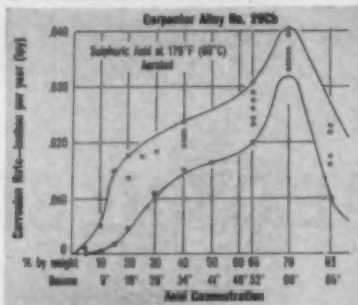
Superior machinability



The selection of Carpenter Stainless

No. 5 (Type 416) for this level wind shaft for a fishing reel gave the manufacturer good machinability and eliminated expensive handwork on the shaft. It also provided excellent resistance to corrosion and unbeatable wearing qualities. A good example of a wise choice in metal selection.

Better corrosion resistance



The wide range of stainless steels available offers the designer the exact degree of corrosion resistance necessary for almost any corrosive environment. For mild corrosives, inexpensive Carpenter No. 1 (Type 410) can be used; for extremely severe corrosives such as hot sulphuric acid solutions, Carpenter No. 20Cb should be specified. For other corrosives, one of the many other stainless steels will be the most economical material for you to use.

Carpenter No. 20Cb is a special alloy first produced by Carpenter in wrought form. Its excellent resistance to hot sulphuric acid is shown in the chart above. For information on its resistance to other corrosives, send for booklet, "Super Corrosion Control."

Easier quality control

Here's an application where Carpenter Stainless No. 8 (Type 303) provided an unexpected bonus! These bushing and shaft assemblies for a push-button unit in an explosion-proof switch were formerly made from a non-ferrous metal. After switching to Carpenter Stainless No. 8 (Type 303) to gain

more uniform machinability and non-corrosive properties, this customer eliminated a costly inspection operation on the finished shafts. This was due to the consistently true size of the No. 8 bars (total tolerance: .0005" as supplied by the Carpenter mill).



Carpenter Stainless is available to the designer in many forms. Billets, bars and wire in a wide range of sizes . . . strip, tubing or pipe of varying thicknesses. Whatever form best suits your needs, you'll find one unique feature of Carpenter Stainless . . . its *consistent uniformity*. There's never the slightest change in composition in any one grade of Carpenter Stainless, no matter how big the order. Day after day, year after year, each melt of Carpenter Stainless is carefully controlled with the best equipment and human effort to bring you a reliable, consistent material, unsurpassed in uniformity. When the product you design goes into production, this consistent uniformity becomes extremely important. Specify Carpenter Stainless, and take a big step toward approval of your project.

Technical data available



Complete information on properties and characteristics of all grades of Carpenter Stainless is available in data sheet form. Send for yours today.

Carpenter steel

you can make it **consistently** better with Carpenter Stainless Steels for specialists

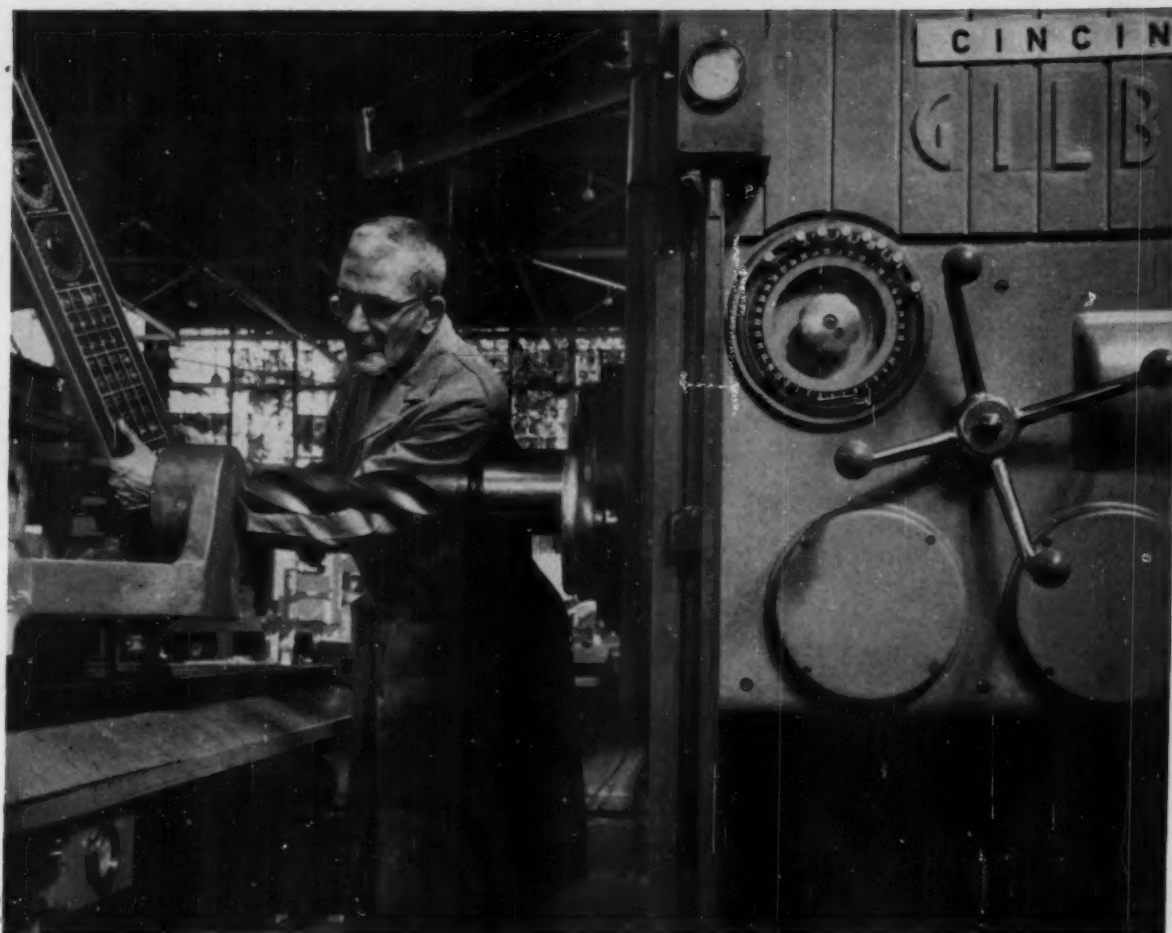


The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Export Dept., Fort Washington, N. Y.—"CARSTEELCO"

Alloy Tube Division, Union, N. J.

Webb Wire Division, North Brunswick, N. J.

Carpenter Steel of New England, Inc., Bridgeport, Conn.



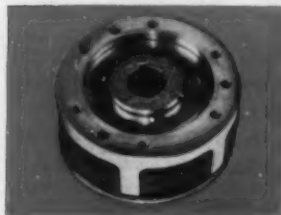
GILBERT MACHINE'S HORIZONTAL BORING MILLS, WITH BENDIX ELECTRIC CLUTCHES, CUT JOB TIME BY 83%

In milling, drilling, boring, and tapping diesel engines and components, Cincinnati Gilbert Machine Tool Co. Tape-Controlled Horizontal Boring Mills do jobs in up to 83% less time.

For their boring mills and automatic positioning machines, Cincinnati Gilbert selected Bendix® electric tooth and disc-type clutches for feed and traverse mechanisms. Reason: Bendix electric clutches meet the

need for compact design, dependable performance, uniform speed of response, extreme accuracy.

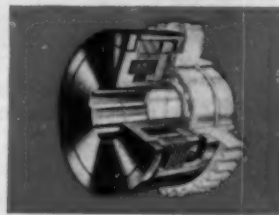
Bendix electric friction and tooth-type clutches are simple, compact, easy to install. Have no external shafting mechanism. Deliver greater torque than mechanical clutches of the same size. Want these advantages? Write today for more details. Eclipse Machine Division, The Bendix Corporation, Elmira, New York.



Bendix electric tooth clutch—positive, high torque transmission. No idle torque. Wet or dry applications. May be engaged at relative speeds. Available in 40 to 40,000 ft.-lb. capacities.

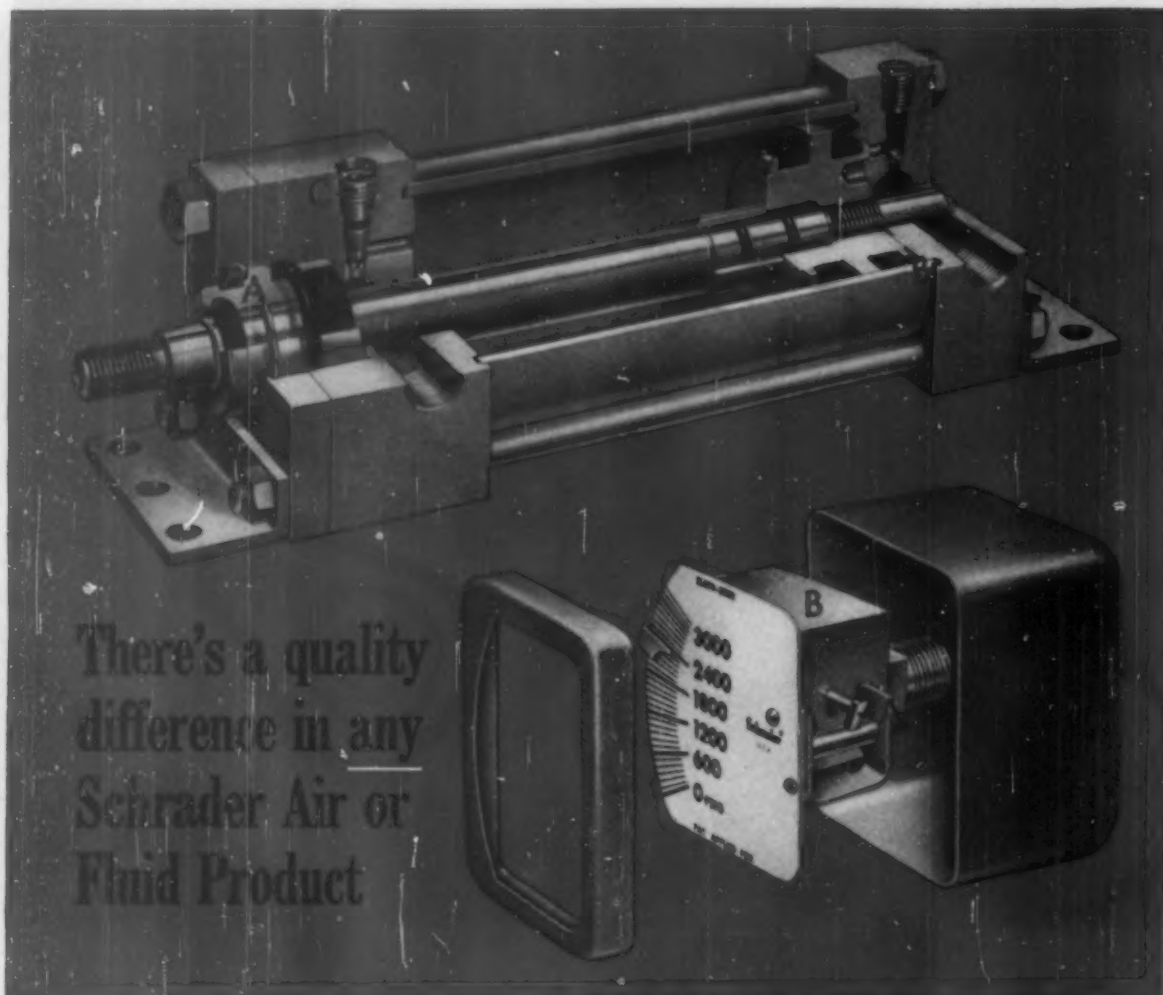
Export Sales and Service: Bendix International, 205 E. 42nd St., New York 17, N.Y.

Bendix electric multiple disc clutch—magnetically isolated disc stack. Ideal for step-by-step acceleration of large masses. Wet or dry operation. Available in 10 to 16,000 ft.-lb. capacities.



Bendix-Elmira





There's a quality
difference in any
Schrader Air or
Fluid Product

EXAMPLE: Schrader Square-end Cylinders not only have quality built into every part, but feature many extras. For instance, the unique cartridge-type bronze bearing assembly (A) is easily removed by releasing just one retaining ring—no need to dismantle the entire cylinder for bearing maintenance. Special “step” design cylinder seal (B) assures perfect alignment and positive seal without danger of gasket damage. Below surface cushion adjusting screws (C) are protected from damage but fully accessible. They lock to eliminate loosening due to vibration.

Interchangeable with all JIC cylinders, Schrader also pro-

vides a variety of mountings. Special bushings are available for bone-dry piston rod in hydraulic operation.

ANOTHER EXAMPLE: Schrader's new direct action Hydraulic Gauges without mechanical linkage (A) eliminate fatigue failure of internal parts. They can withstand 100% overload without damage to accuracy, and are triple-damped (B) to eliminate indicator oscillation from pump pulses, surges, or shock that would damage other types. Can be maintained and calibrated easily in the field. PSI pressure ranges 0-500, -1500, -3000, and -5000.



FULL LINES OF QUALITY AIR CIRCUIT COMPONENTS • OFF-THE-SHELF SERVICE AND INFORMATION FROM YOUR NEARBY DISTRIBUTOR • STAFFED WITH AIR CIRCUIT EXPERTS • CONSULT YELLOW PAGES OR WRITE FOR HIS ADDRESS



A. SCHRADER'S SON
Division of Scovill Manufacturing Co., Inc.
476 Vanderbilt Ave., Brooklyn 38, N. Y.

QUALITY AIR CONTROL PRODUCTS



Snowplow chews up avalanches at 36 tons a minute

How steel with Nickel in it delivers the brawn behind the bite

Chewing through mountainous drifts to rescue a snow-bound town, this plow can devour 2,200 tons of snow an hour.

It bites through solid ice and deep snow. Or strips a new-fallen six-inch blanket from a superhighway at 30 mph.

Drive shaft and gears run a gauntlet of shocks as the plow churns through rocks and stumps buried under stone-hard snow. That's one big reason why two nickel alloy steels, AISI 4320 and 3140, are used for these heavily stressed transmission parts.

Nickel gives steel the strength and toughness essential to a snowplow's drive shaft that must perform under brutal wrenching, twisting shock loads in arctic cold.

Putting stamina where it counts is just one of the things you can do with

Nickel. In addition to providing muscle, Nickel can also help alloys withstand the intense heat generated by supersonic flight. Or shrug off the deep cold of liquid helium. And every industry knows the value of Nickel in combatting corrosion.

When you have a metal problem, look into the possibility that Nickel or one of its alloys might be the answer. Write for our "List A." It tells you of technical literature helpful to all industries. A copy is yours on request.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street



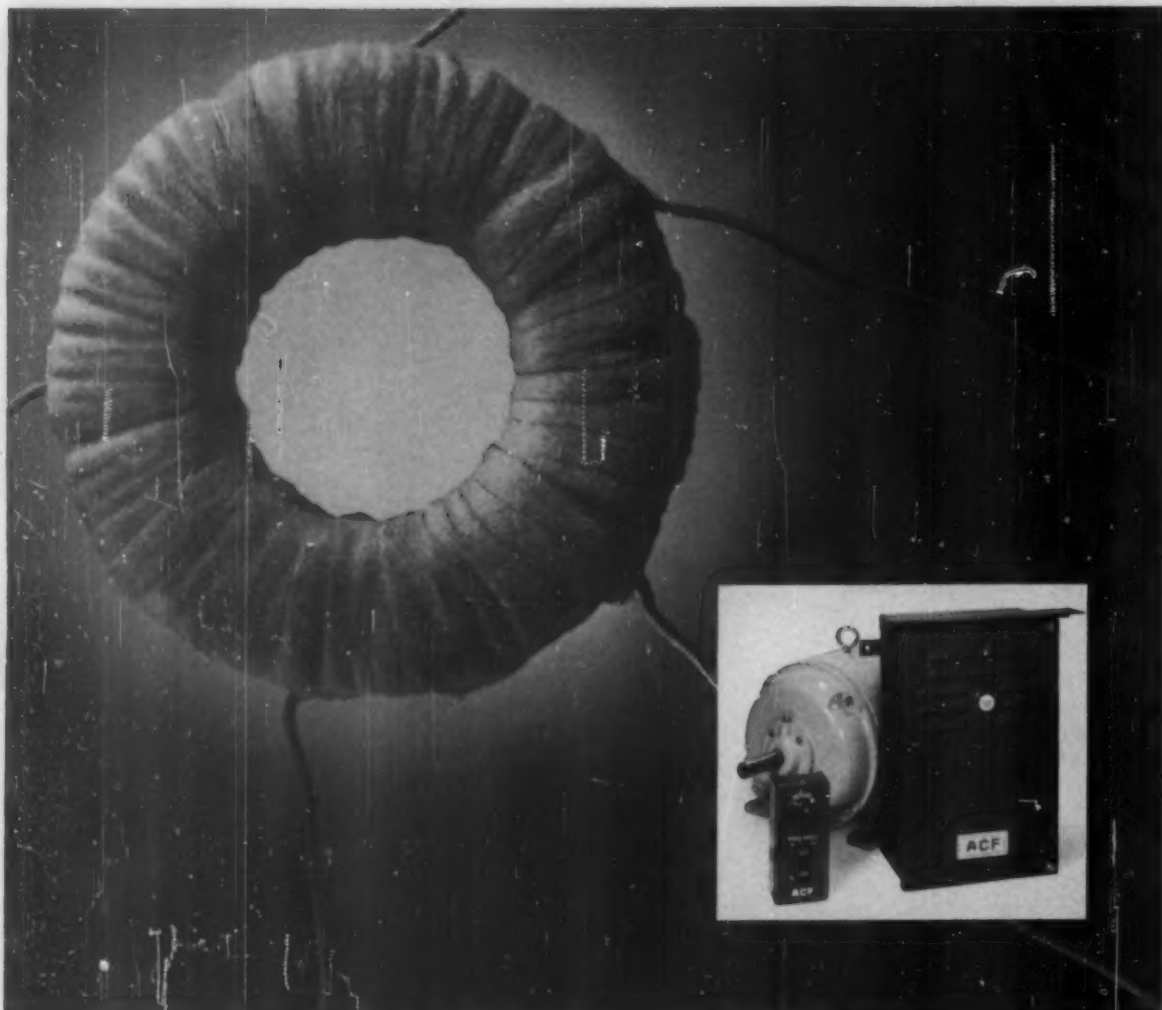
New York 5, N. Y.



Transmission shafts are made of AISI 4320 nickel alloy steel. Drive and spline bushings are AISI 3140. Snowplow by American Snowblast Corp., Denver, Colorado.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER



MOTOR CONTROL "NERVE CENTER"

ACF ADJUSTABLE SPEED CONTROLS respond instantly to speed variations due to load changes. The patented ACF Magnetic Triggering "nerve center" provides precise control of firing angles; avoids response to spurious transients; gives driving power under extremes of temperature, line voltage and frequency. ACF drive systems from 1/100 to 15 horsepower are easily installed and are superior in any application requiring adjustable speed at constant torque.

ACF STEPLESS MOTOR CONTROLS operating from an AC source, are smaller, lighter, more economical than competing systems—give smooth, precise regulation over a wide range of speeds regardless of load variations. The "nerve center" eliminates the need for tubes and insures instantaneous, repeatable control. ACF compact drive systems, for both fractional and integral HP DC operation, are available as off-the-shelf items.

For full information, write or call Paramus Plant, 11 Park Place, Paramus, N. J. Telephone: COlfax 1-4100.

ACF ELECTRONICS
DIVISION

ACF INDUSTRIES



Right to a thousandth when you adjust with *LAMINUM*[®]

Just *p-e-e-l* the laminations—it's that easy to get accurate assemblies with LAMINUM . . . even as close as a thousandth. No machining. No grinding. No counting. No stacking. No milking. And no need for stand-by equipment.

LAMINUM is versatile, too. You have a choice of brass, mild steel, stainless or aluminum . . . of .002" or .003" laminations . . . of plastic bond or metallic bond. And now also in Titanium with laminations of .003"!

Whatever your choice, we'll custom-stamp LAMINUM to your own rigid specifications . . . any size, any shape, and quantity . . . to look and act like solid metal . . . to help you produce more and better assemblies . . . in less time . . . and at less cost.

That's what makes LAMINUM so practical. So popular. So easy to use. Revised SHIM DESIGN FOLDER No. 4 gives complete up-to-the-minute engineering data. Send for your copy today.



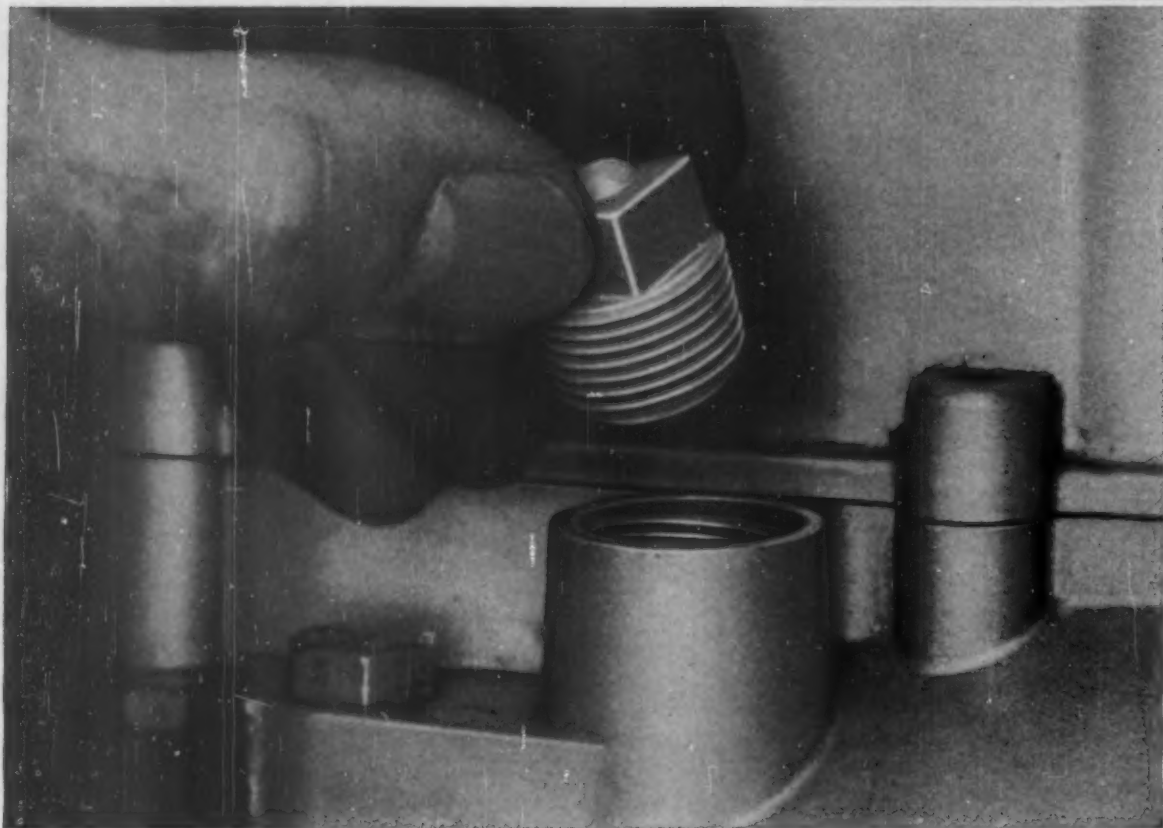
THE LAMINATED SHIM COMPANY, INC.

Home Office and Plant
1211 Union St., Glenbrook, Conn.

West Coast Sales and Service
600 Sixteenth St., Oakland 12, Calif.

Circle 262 on Page 19

New, complete line of RB&W molded plugs



Avoid damage to threaded holes...get leakproof seal, too

You entirely eliminate the risk of damaging a costly tapped hole with RB&W molded plugs. If inadvertently crossed-threaded, their plastic material yields to metal threads—especially important where the tapped holes are in malleable metals.

They seal tightly under pressure, too. That's because all RB&W plastic plugs are molded hollow. Fluids under pressure exert radial forces that expand threads for an even tighter, dry, plastic-to-metal contact.

They resist corrosion, usually cost less than their metal counterparts, are available in various materials for various jobs.

DELRIN®—All-purpose RB&W Delrin® plugs ideally seal gases or fluids in compressors, pumps, valves, pneu-

matic and hydraulic systems, or any service involving contact with petroleum derivatives. Delrin plugs have metal-like mechanical properties, are suitable for use to 250°F.

NYLON—Made from *heat-stabilized* nylon (Zytel® 103), RB&W plugs withstand temperatures exceeding 300°F, remain leakproof at working pressures to 3000 psi.

NYLON—Made from *hydrolysis-resistant* nylon, (Zytel® 2281), RB&W plugs assure dependable service when continuously exposed to hot water or vapor.

POLYETHYLENE—RB&W polyethylene plugs, in two head styles, economically seal threaded openings to exclude dirt, contaminants, and

moisture during shipping or handling. They can be tightened with fingers or wrench.

Send for data sheet which gives sizes and other specifications. Write Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, N. Y.

(R) Dupont Trademark



Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Additional sales offices at: Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas; San Francisco.

"Y'know, Herm...I think Snap-Tite Couplings can handle this stuff better than you can..."



A complete choice of packers and seals permits Snap-Tite quick-disconnect couplings to handle over 600 different fluids! (*some of them mighty tough*)

Whatever fluid you're working with, chances are Snap-Tite couplings can handle it. Because everyone of the thousands of Snap-Tite quick-connect valved couplings comes with a wide choice of rubber packers and seals, selected according to the fluid in use. The right choice, of course, is vital for the seal is the very heart of the coupling.

To assist you in the proper selection of coupling

seal material, Snap-Tite, with the assistance of suppliers of synthetic rubber materials, has recently compiled a comprehensive Packer Usage Guide—the first of its kind in the industry.

For the Packer Usage Guide, and for complete information on the correct choice of quick-connect, quick-disconnect couplings for the fluids you use, write Snap-Tite, Inc., Union City, Pa.



87-61-02

Snap-Tite Packers and Seals



Snap-Tite
UNION CITY, PA.



#10 CURVING AND CONTOURING HONEYCOMB IS EASY WITH THE RIGHT TECHNIQUE

More Honeycomb Sandwich Used Today Curved or Contoured Than Used Flat

In recent years, improved techniques for handling curved honeycomb materials and producing contoured honeycomb products have reduced this once difficult task to simple, predictable practice. Discussed below are basic techniques for working metal and reinforced plastic honeycomb, after expansion.

Curving Metal Honeycomb



For simple curvature of constant or nearly constant thickness panels, the material is simply roll-formed through a standard sheet metal or Farnham roll. The principal consideration is that the opening between rolls must permit passage of the full thickness of the honeycomb core to prevent crushing. The technique of curving is to pass the honeycomb through the rolls using successively tighter radii until the final finished curvature is achieved.

Low density cores or tight radii require the use of metal slip sheets between the honeycomb and the rollers to prevent damage to the core surface. In some cases the outer slip sheet may be bonded temporarily to the honeycomb to facilitate achievement of extremely tight radii without any damage or opening of the cell structure on the outside surface. The temporary bonded slip sheet is peeled off after final rolling.

Compound curvature of metal honeycomb is achieved by either cross-rolling the parts or by over-forming and then using the anti-elastic tendencies of the material to produce a radius in the cross axis by forcing out the radius in the primary axis.

Curving Glass Fabric Reinforced Plastic Honeycomb



Fiberglass honeycomb used in radomes and some primary structures requires a different curving technique than metal honeycomb. Since glass fabric core is a relatively brittle material, it must be preheated and held to contour during the cooling cycle. Preheat cycles of 500 to 600 degrees at 10 to 50 seconds are frequently used, with cooling cycles of one to two minutes at contact pressure in matched metal, plastic or plaster dies. Usually only a rough approximation of the finished contour is required since the contoured honeycomb is somewhat flexible and will readily conform to the exact contour of the bonding tool even though it may be slightly different than the finished honeycomb contour.

Carving Metal & Glass Fabric Honeycomb

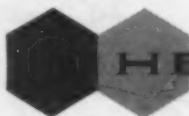


Simple router tooling is all that is required for carving aluminum or glass fabric reinforced honeycombs. Cutter points may be either high speed valve stem cutters or an arbor of the same shape holding a jeweler's saw. In either case, cutter speeds from 4,000 to 15,000 rpm and extremely light tool point loads are normal.

A primary requirement for the carving machine bed is that it must be suitable for producing parts to plus or minus .005 dimension tolerances. As much as five to ten square feet an hour can be carved on simple shapes. In specialized applications, carving rates ten times this have been accomplished.

Hexcel Experience, Specialized Tooling Available To Help Designers

Hexcel's pioneer role in the development of honeycomb has resulted in the design and use of many special machines for pre-curing and machining unusual shapes. These facilities are available to work for you; or, Hexcel engineers will work with you in manufacturing your own forming and carving equipment from Hexcel drawings, and stay in your plant until your own employees are trained in our proven techniques for working honeycomb. Write Dept. C-11 or call for any specific information.



HEXCEL® PRODUCTS INC.

Stronger, lightweight materials for industry

Executive Office: 2332 Fourth St., Berkeley, Calif.

Plants: Berkeley, Oakland, El Segundo, Calif.; Havre de Grace, Md.

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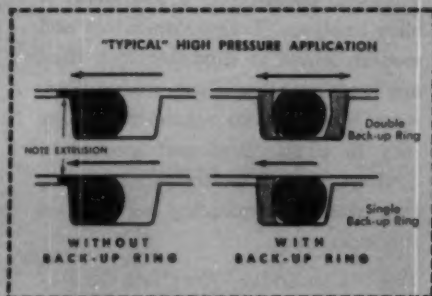
**NOW—Increase O-Ring Life and
Reduce Costs with...**

Parbak*

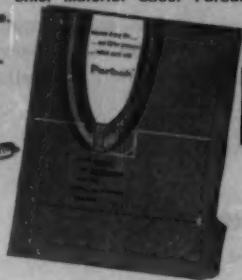
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simplified, easy-to-assemble, resists higher pressures!***

Here's the first really new
back-up ring in years...

Test after test, both in the field and
laboratory, has proved that Parbaks*
greatly increase O-ring life.
In addition Parbaks* improve lubrication,
are easy to assemble, and resist higher
pressures — yet they actually cost less than
back-up rings for similar useage!



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now. Send for catalog 5482 — 8 pages of de-
sign data and other material about Parbaks*.
It's free, of course.



Parker SEAL COMPANY
Culver City, California and Cleveland, Ohio
A DIVISION OF PARKER-HANNIFIN CORPORATION

Circle 266 on Page 19

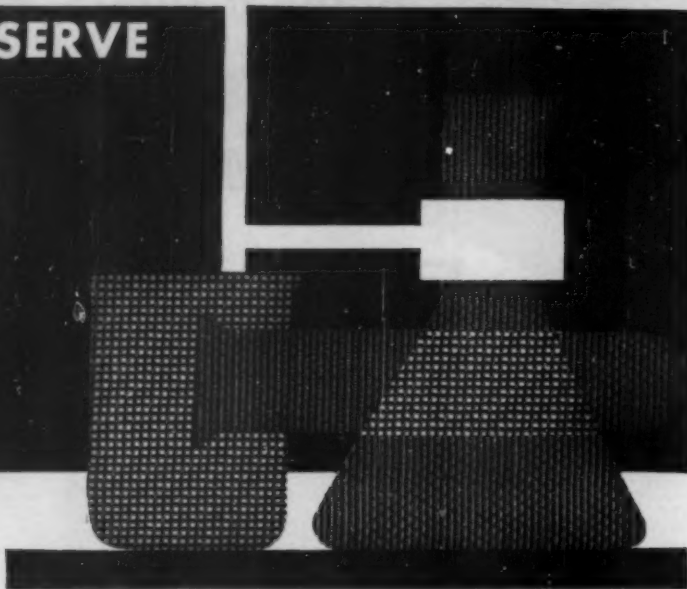
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use wire cloth in critical operations?

THEN THEY DESERVE

Cambridge

WIRE CLOTH
QUALITY &
SERVICE



What is Cambridge Quality?

Wire that consistently meets metal or alloy analyses. Trained operators and modern looms to produce cloth from any metal or alloy in any weave. Constant inspection to assure high accuracy in mesh count and mesh size. Craftsmen to make fabrications in any size, shape or quantity to exacting specifications.

This is Cambridge Wire Cloth Quality.

What is Cambridge Service?

Prompt answers to mail or phone inquiries. Experienced Field Engineers—experts in their field—who can help you select the wire cloth to do the best job at lowest cost. Prompt deliveries. Large stocks of frequently used cloth for immediate shipment. Follow-up service to see that our product is giving you the results you want.

This is Cambridge Wire Cloth Service.

Your Cambridge Field Engineer can show you how Cambridge quality and service can help you in your operation. Call him at any time. He's listed in the Yellow Pages under "Wire Cloth". Or, write direct for illustrated 120-page catalog.

Refer to our technical data sheet in **CHEMICAL ENGINEERING CATALOG**, Page 185.



The Cambridge Wire Cloth Co.

Department N • Cambridge 11, Maryland

Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts,
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UNIVERSAL MOTORS

1/50 to 1 horsepower

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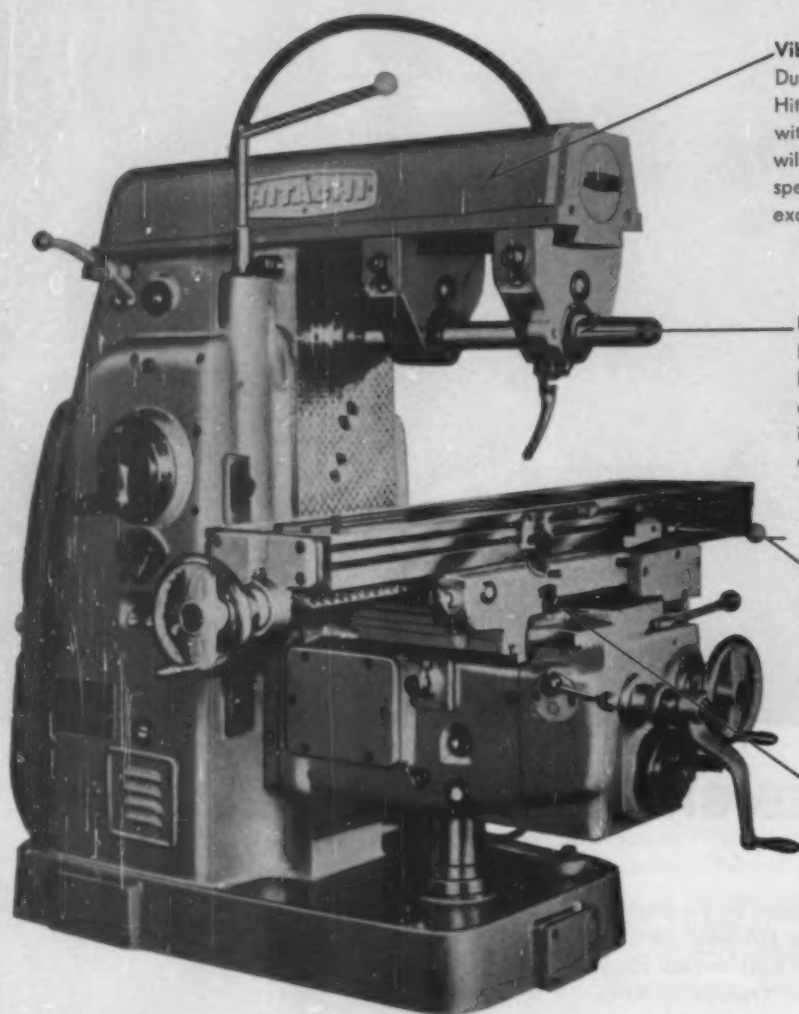
ROBBINS & MYERS, INC., Springfield, Ohio

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Circle 268 on Page 19

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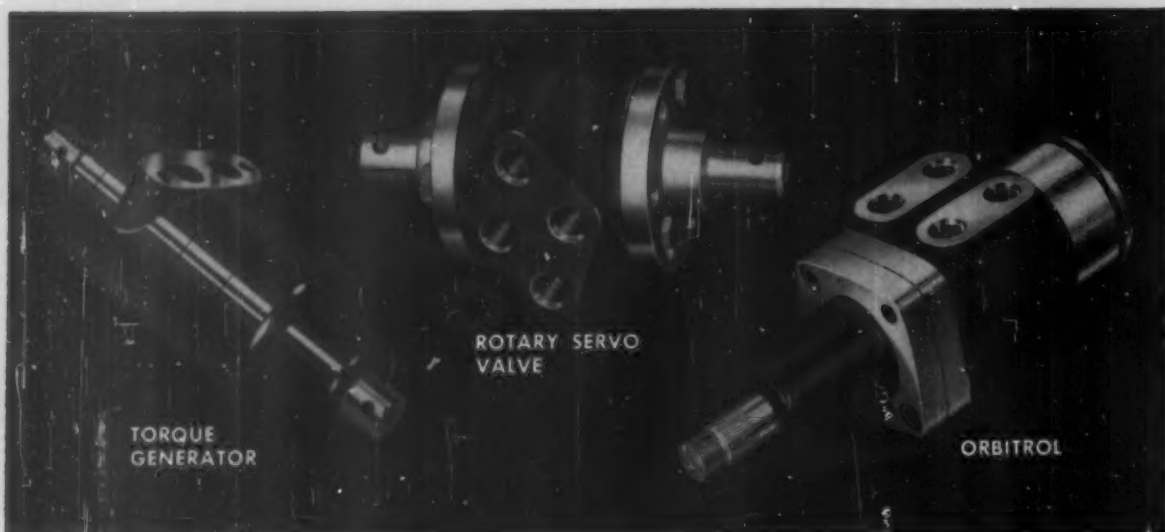
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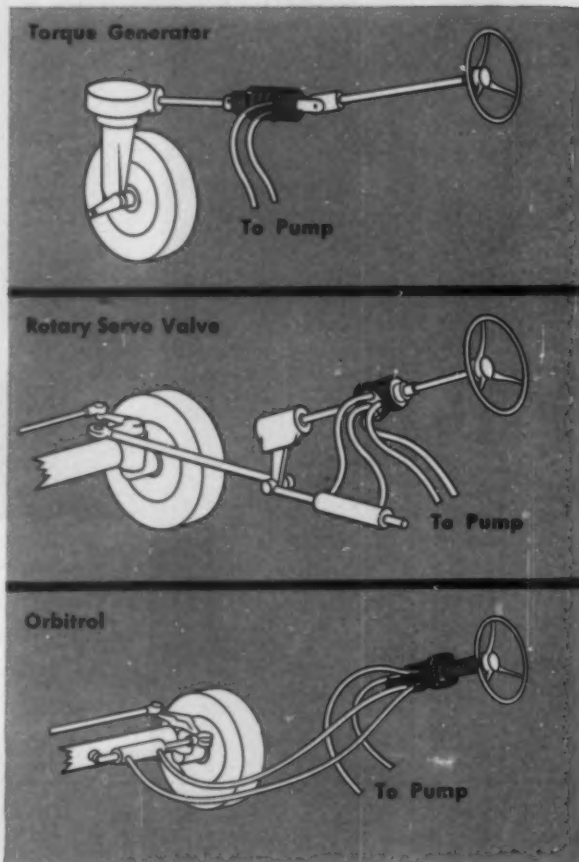
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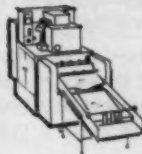
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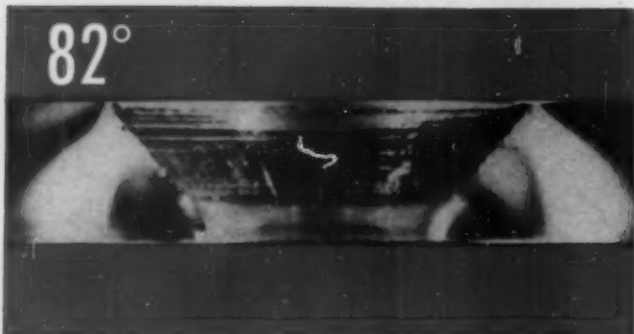
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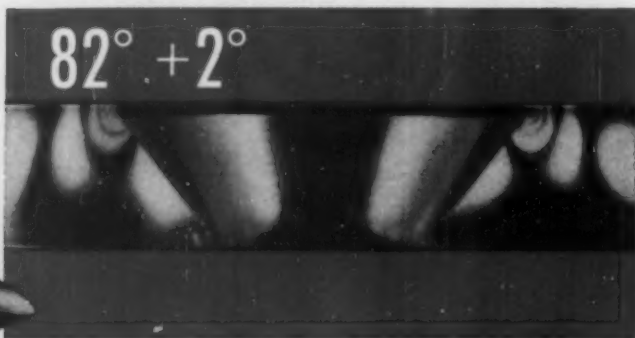
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**this Allen
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PQA makes it certain that an Allen Flat Head Cap Screw has contact throughout the angle of the head with the mating countersunk hole. This assures the strongest possible fastening. In this photo, made with polarized light, you can see the stress points throughout the chamfer.



Industry standards allow a tolerance of $+2^\circ$ in the head angle. Allen Flat Heads manufactured to this tolerance have greater bearing at the top of the head—shown by the stress patterns in this polarized light photograph.

*PRODUCT QUALITY ASSURANCE

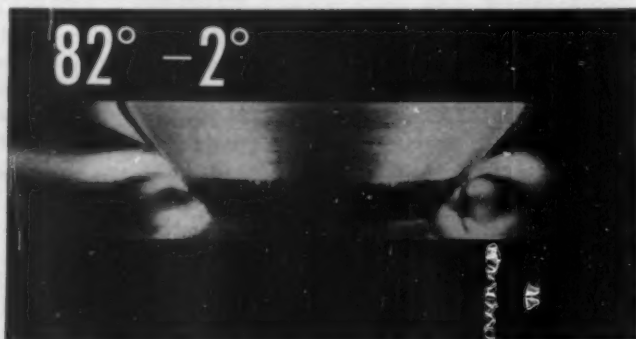
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Industry also allows a tolerance of -2° in the head angle. But Allen does not utilize this negative tolerance. The reason—it is entirely possible to have head seating efficiency reduced because of excessive interference in the head-shank area. The photo shows high bearing stress in this area—with risk of breaking prematurely.

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Circle 276 on Page 19





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MINIATURE VALVES

0 SERIES VALVE



OVS2



OVS2-A



OVM2-S2



OVM2-S2-A

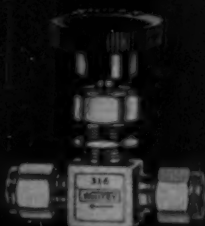


OVM2



OVM2-A

1 SERIES VALVE



IVS4



IVS4-A



IVM4-S4



IVM4-S4-A



IVM4



IVM4-A

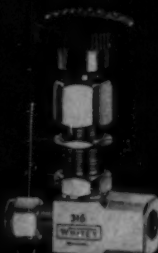
2 SERIES VALVE



2VS4



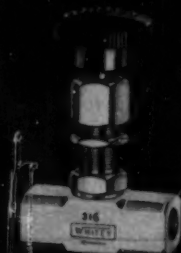
2VS4-A



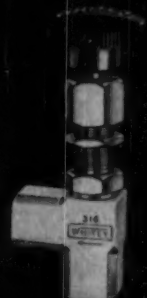
2VF4-S4



2VF4-S4-A



2VF4



2VF4-A

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For color coding purposes, colored handles may be specified when ordering WHITEY Valves.

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Complete technical data on WHITEY Valves available on request

Circle 272 on Page 19

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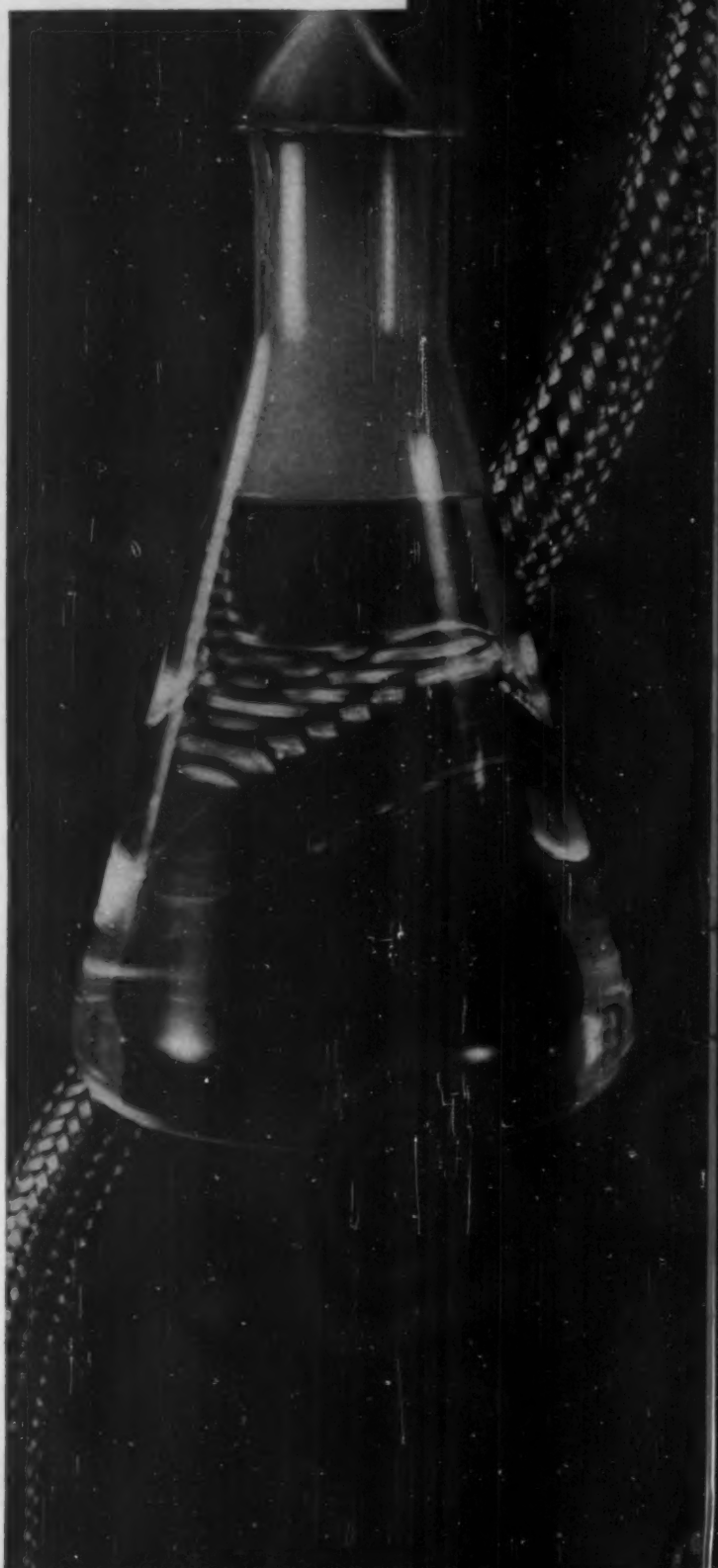
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61-839

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ANACONDA®
METAL HOSE DIVISION

Circle 279 on Page 19





Pig in a Poke

CONSUMERS know too little about the things they buy. If you give a storekeeper \$1.98 for some item of hardware, you both know what his share of the trade is—an amount equivalent to 198 pieces of chewing gum. But you don't really know the value of the item you received. You don't know why it works or what it is made of, because nobody feels it necessary to tell you.

The original equipment market, which is dominated by hard-headed engineers, bears little resemblance to its frivolous counterpart—the consumer market. An engineer wouldn't think of selecting a hydraulic pump for his company unless he knew all of its specifications, its peculiarities of operation, and perhaps even the man who designed it. Yet that same engineer will buy a transistor radio on the basis of one known fact—his wife likes white plastic appliances.

The new crop of 1962 automobiles has brought some noteworthy claims, such as extended greasing and service intervals. Since all "How come?" questions were answered

with shrugs, this irate customer bought one intuitively, expecting that when the car was delivered the owner's manual would explain all things. Words can't describe the marvelous promotional material to be found in that book. It wasn't a matter of just buying a car. It was like joining some select fraternity. Welcome aboard! You are now a person of taste and discrimination. The manual also told what the steering wheel was for and where to find it, how to operate the cigarette lighter—things like that.

But what are the gear ratios in all four positions of the automatic transmission? Is it really a four-speed transmission, or is our barber misinformed? How does the suspension system work? Was it necessary to increase the size of the oil passages in the engine block to get a longer service interval?

Why don't they tell consumers anything? Because we haven't asked?

Sam Barnes
ASSISTANT EDITOR

Why

new products fail

The six main reasons why only one new product out of twenty is a success.

PHILIP MARVIN

Division Manager
Research and Development Div.
American Management Association
New York

NINETEEN out of twenty new products are failures. Not all of these failures are spectacular—the newly launched product may not sink immediately under the salvos of commercial warfare. It may just develop slow profit leaks that take it down to Davy Jones' locker before anyone is even aware that there's trouble.

Based on the experiences of a number of companies, there are six primary reasons why new products fail. Perhaps a seventh could be added—fear of failure. A new product program can develop slow leaks and finally founder merely because everyone's afraid to act—and take the chance of making a mistake. After all, no-one points a finger at those who stall for time.

These uncertainties can be avoided, and risks of product planning minimized. A lot can be learned by studying product failures, particularly these six main problems, as a basis for developing skill in avoiding the usual product-planning pitfalls.

1 Timing Was Off

The best-planned programs can trip on timing. In new-product planning, few things seem more certain than the fact that there is a time and place for everything. Put another way, every part of a new product program must fit a master time schedule.

To illustrate the importance of timing, here is how one company missed a market by bad timing. The proposed new product was given the green light after careful appraisal and screening. It looked like a real money maker. It was a specialty item for the Christmas market, one accounting for 80 per cent of the sales of this type of item.

Two years was estimated as the time needed to develop the idea, get it into production and fill the pipelines between producer and consumer. But un-

foreseen difficulties arose and delays occurred. Because the importance of tying the product's introduction to the Christmas market was overlooked, delays weren't offset by extra efforts. As a result, the market was missed by six weeks—six weeks that cost a loss of 80 per cent of one year's sales.

In another case involving an industrial product, timing played a different role with equally costly consequences. One large manufacturer of electronic components planned to introduce a new tape-recording device adapted to visual images. Engineering development was allowed to lag. As a result, a competitor was the first to introduce apparatus which was quickly established as a recognized standard in the television industry.

Some delays can't be circumvented. No amount of attention paid to time schedules can prevent unforeseen factors from arising. This isn't the function of time schedules. Their job is to highlight dates that have an important bearing on the profit picture. Then, when delays do occur, it is possible to make a rapid appraisal of the probable cost of these delays, and to relate this cost to the cost of offsetting these delays with accelerated programs.

Either too much or too little, timed too soon or too late, can cause consequences of serious proportions. "Too little and too late" are some of the saddest words heard in discussions of new-product programs. Equally unfortunate is the opposite extreme of "too much and too soon." This can be costly too! Timing is the important factor in avoiding these bugaboos of product planning.

Timetables are vitally essential to the success of new-product development. Timetables should reflect recognition that dates are coupled to dollar signs, and that time periods are tied to costs. Compromises must be made, fitting the two together. Once this is done the importance of these decisions should not be forgotten. Too often, careful planning efforts, once completed, are treated as an incum-

brance of the past rather than as a guide to the future. When this happens, all of the effort that has gone into planning is wasted.

Departures from timetables should be viewed with alarm. They should signal the need for prompt reappraisal of the program. Timing is too closely tied to profits to be neglected.

2 The Product Wasn't Practical

Some good ideas just don't pass the test of commercial feasibility. It isn't always easy to distinguish between what can be done and what is commercially feasible. The difference between these two is the difference between profit and losses. It isn't enough to be able to produce the product; it must be possible to sell it at a profit. Overlooking this fundamental fact would seem to be almost impossible.

But the challenge of technical achievement sometimes has a temporarily blinding effect. Individuals who are otherwise quite objective in their outlook frequently fail to be objective when faced with the opportunity to score a technical triumph. From a business point of view, profits are the only ultimate triumph.

Failure to pass the test of commercial feasibility has come about in many ways. Here is a rapid rundown of some of the more familiar tales of woe: 1. "It was easy to produce one, but we ran into difficulty with production lots." 2. "It was a good product but it took us too long to tool up." 3. "We didn't realize how much it would cost to develop the market." 4. "We didn't understand what our customers really wanted."

The ultimate test of commercial feasibility lies in the answer to two questions: 1. Can it be made? 2. Can it be sold at a profit? Affirmative answers are needed.

Industrial products and consumer items incorporating advanced engineering technology are particularly sensitive to the test of commercial feasibility. The challenge of technical achievement has already been cited as one of the reasons why new products are pushed to completion without weighing all of the factors. Beyond this is the difficulty of appraising the final product of highly complex technology until that product actually takes shape. Performance characteristics are often critical factors in determining commercial feasibility. In many cases these can only be determined by building prototypes.

3 Customer Needs Changed

New products are created and developed in a dynamic environment. Carefully conducted surveys may reveal specific customer needs. But these needs can change before sufficient time has elapsed to capitalize

on them.

The time factor involved in making a profit on a new product can be quite long. Products must not only be created, produced and marketed. They must also enjoy a sufficient span of sales to build an attractive return on the investment. If the risk is great that the span of sales may be too short, it's a good idea to reappraise the situation.

Some years ago, a company concluded that there was a market for an automatic electric razor-blade sharpener. This was based on a carefully conducted study. By the time the product was developed, needs had changed. The price of razor blades had been drastically reduced. Ejector-type dispensers were available that eliminated handling sharp blades. The introduction of the electric shaver captured a portion of the potential market. The need to resharpen razor blades was largely eliminated.

One of the common errors in analyzing customer needs is to consider the survey completed once product development gets under way. During development stages, more than ever before, it is important to maintain vigilance over potential markets. The investment in a new product mounts steadily during the development phase. When factors arise that alter sales prospects, they should be detected as soon as they appear. Nothing is gained by adopting ostrich-like tactics. Burying one's head in the sand provides no protection.

Action that has been taken, and money that has been spent, can't always be salvaged. Early detection of new factors which change original assumptions prevents needless additional expenditures of time and energy. Programs can be altered to provide new direction. Resources can be diverted into more profitable channels.

Consumer needs are always changing. Steadily increasing watchfulness over these changes is needed as the investment in new products grows.

4 Basic Assumptions Were Forgotten

Every new product is based on specific assumptions. Here were some assumptions of one manufacturer in developing an automatic multipurpose machine tool: 1. An expanding market for automatic equipment. 2. An opportunity to increase profits by entering this market. 3. A desire to expand in this direction. 4. A willingness to accept the added burdens on management's time.

The Engineering Department embarked on the project. They came up with a special-purpose machine tool that integrated a time-consuming sequence of operations into one operation. The machine was marketed, not too successfully. For some time, management's energies were dedicated to making a success of this project. Everyone is familiar with the flurry of activities when a company attempts to achieve such goals. Sales and engineering conferences, dealer meetings, executive huddles occupy management's time to the hilt.

As frequently happens when the going gets rough, someone began to wonder how the company got into the muddle. Thinking back, some of the basic assumptions were recalled. In this case—an automatic multipurpose tool—to enhance future profits—in an expanding market. The tool as developed didn't fit. Basic assumptions had been forgotten.

It is easy to forget the assumptions on which decisions are made. Engineers and scientists get lost in the details of their work. They fail to check their directions periodically. They follow clues as they must, but fail to defer interesting leads that run counter to more immediate objectives. Salesmen and marketing men are prone to lose interest in longer range developments once the enthusiasm, kindled by a new idea, has spent its force. Management is distracted by day-to-day activities.

New products are frequently neglected until too late. They often stray far from original directions because basic assumptions were forgotten.

Basic assumptions shouldn't constitute such a rigid framework that they aren't adjustable to new intelligence as it develops. As knowledge and information develops that suggests changes in basic assumptions, the entire program, along with the basic assumptions underlying the program, should be reviewed. Changes should reflect new conditions and new needs. Basic assumptions should be altered only by aggressive, informed action. Changes should never be a by-product of neglect.

5 Goals Weren't Clearly Defined

The driving force behind successful new products lies in well-developed corporation objectives. It's exceptional when executives are able to make a clear-cut statement of their companies' objectives. It's rarer still when these statements come to a common focus. Yet concentrated, co-ordinated effort depends on common goals. Lacking these, executives are apt to drive toward opposing ends.

The development group in one company spent sizable sums developing a diversified product line, while the sales group was concentrating on establishing a leadership position in a single industry market. In another case, a chemical company developed a food-processing operation subsequently judged too foreign to established business for further exploitation.

With odds as unfavorable as they are to the success of any new venture, new products should have the benefit of co-ordinated efforts within the company if they are to have any chance of success.

Product managers work most effectively when goals are clearly defined. These goals are linked to corporate objectives. Indeed, these product goals are one of the most important facets of corporate objectives. Nothing is more important to business success than a company's products. And a continuing flow of new products is necessary to inject added vitality into the company's product lines.

New products frequently fail because of conflicts of interests within the confines of the company's own operations. The reason: Confusion over objectives. When top management fails to establish objectives, this function is usurped by those in widely scattered activities at lower echelons. Goals established at these levels will be motivated by many factors, some good and some selfish. At best, they never achieve the objectivity and cohesiveness needed for successful new-product planning, production, and promotion.

6 Product Competed with Customers' Sales

Products aren't always sold to ultimate consumers. Many middlemen may be involved between an initial sale and the final customer. A fiber producer sells to a yarn producer, who in turn sells to a knitting mill, whose customer may be a converter. The chain doesn't stop here. Converters sell to wholesalers, who sell to apparel houses, who sell to distributors. Apparel then passes to retailers and finally to ultimate consumers. There have been many customers for the original fiber. The fiber itself was probably produced from a chemical intermediary that had already passed through a number of sales sequences.

Thinking about new products is sometimes projected to things the company buys and sells. This is dangerous territory. Particularly so because thinking turned into action can have serious impact on presently profitable products.

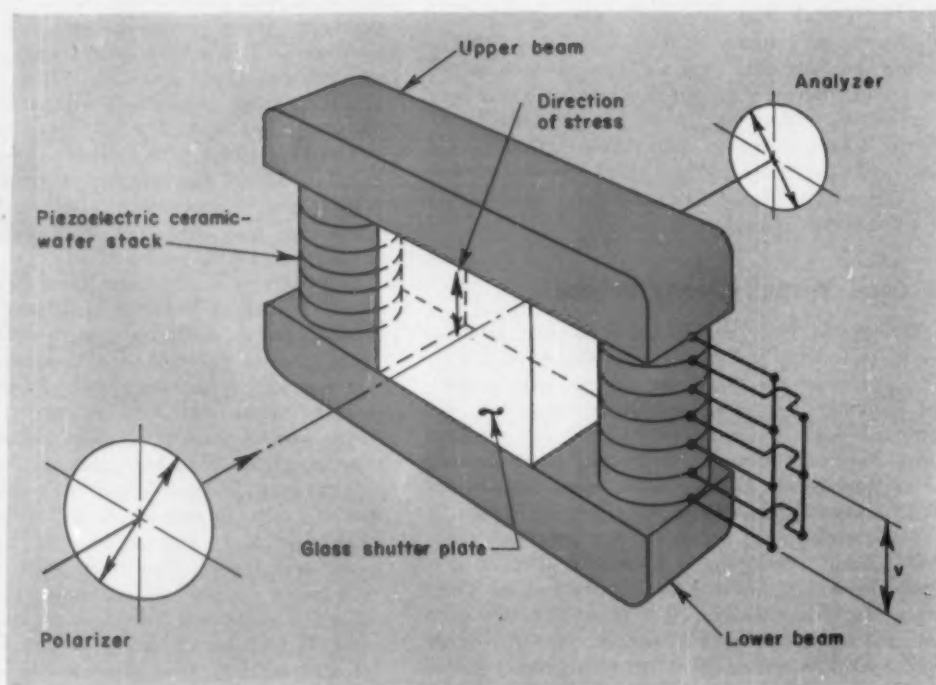
Competing with customers, or suppliers, may prove costly. Successful business experience can't always be projected as profitably and as easily as thinking about greener pastures of customers and suppliers.

A company's customers and suppliers operate in markets having their own distinctive characteristics. In the various parts of the same industry, specialized experience and knowhow must be acquired. Technologies may also be different. It's a mistake to assume that it's easy to expand in any direction from an established spot. Reputation may help some, but profits will largely depend on good, hard work.

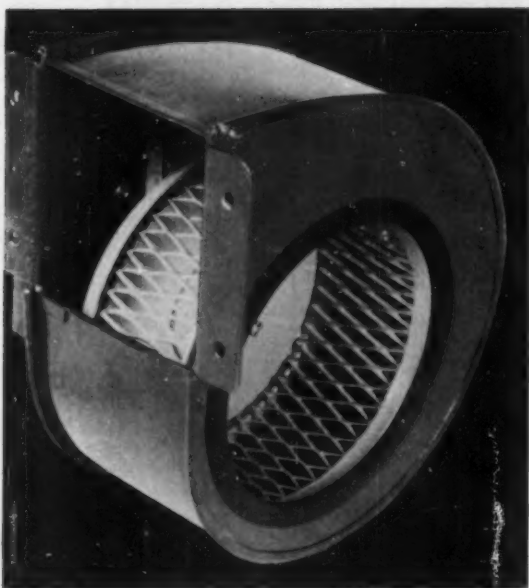
Invading territory of customers and suppliers is an act of commercial warfare. Retaliatory measures must be anticipated. In competing with customers for their markets, some of these customers may shift to other suppliers. This means lost sales that must be offset by additional orders from new markets yet to be exploited by relatively new selling teams. Customers and suppliers, in retaliation to encroachment, can expand their individual spheres of operation too. They will share equal opportunities for success.

Before developing new products that compete with customers or suppliers, the consequences of such steps should be carefully weighed. Potential gains should be based on an evaluation of retaliatory strategies of either a defensive or, more importantly, an offensive nature.

SCANNING THE FIELD FOR IDEAS



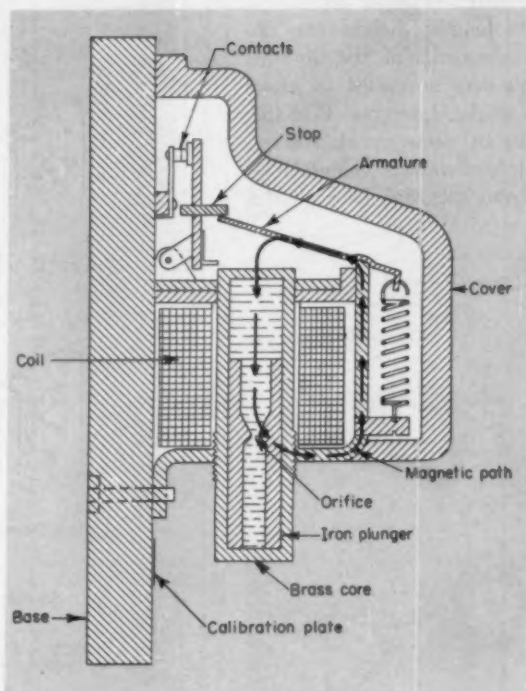
Stressed glass shutter produces exposures from 100 microseconds to several seconds. Mechanical strain on the glass, induced by the piezoelectric ceramic-wafer stacks, generates an optical birefringence which rotates a beam of polarized light. Thus, the duration of the light transmission is controlled by the duration of the voltage pulse applied to the ceramic-wafer stack. Principle employed in a shutter by Electro-Optical Instruments Inc., Pasadena, Calif.



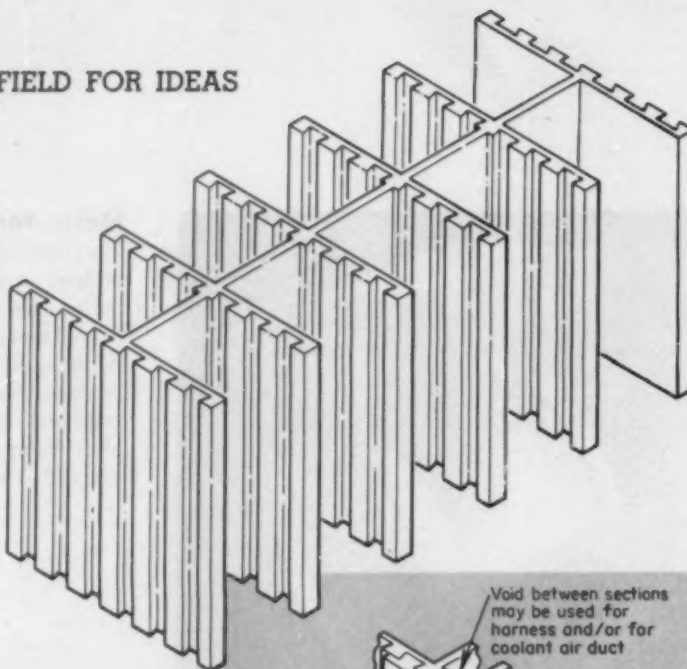
Mesh forms blades

in a centrifugal blower. The inclined strands, produced during the forming of the expanded-metal mesh, form multiple, lightweight, easy-to-make blades. Principle employed in a blower by Heat Pump and Refrigeration Ltd., London, England.

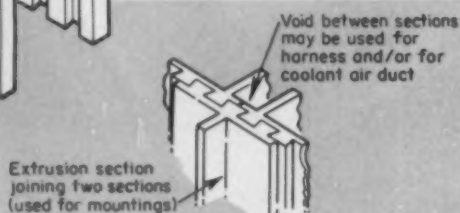
Shock-absorber relay damps current peaks in a motor-overload relay. When relay-coil current exceeds a preset value, the iron plunger rises in its liquid column. The concentrated flux then attracts the armature and opens the contacts. An orifice in the plunger damps out the effect of short current peaks. Principle employed in a protective relay by Clark Controller Co., Cleveland, Ohio.



SCANNING THE FIELD FOR IDEAS



Extruded electronic chassis permits modular approach to mechanical packaging. Length is obtained by cutting the magnesium or aluminum extrusion to length; height may be varied in increments of the dovetail pitch; width may be varied in increments of a single *H* section. Principle employed in an electronic chassis, reported by John Belanich, General Dynamics/Astronautics, San Diego, Calif.



Typical Combination of Two Extruded Sections

Extrusion section mounting tab or guide rail



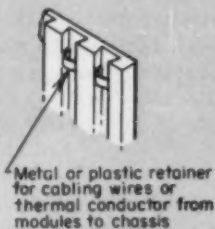
Typical Clamp Mount



Typical Mounting Tab or Guide Rail



Typical Clamp Mount

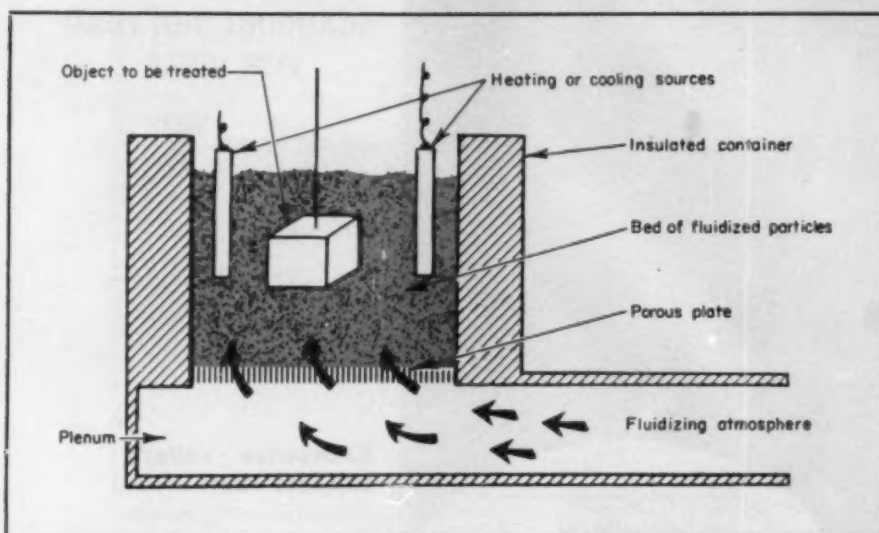


Spring Clip

Radiating fins as required

Dust Cover

Gasket

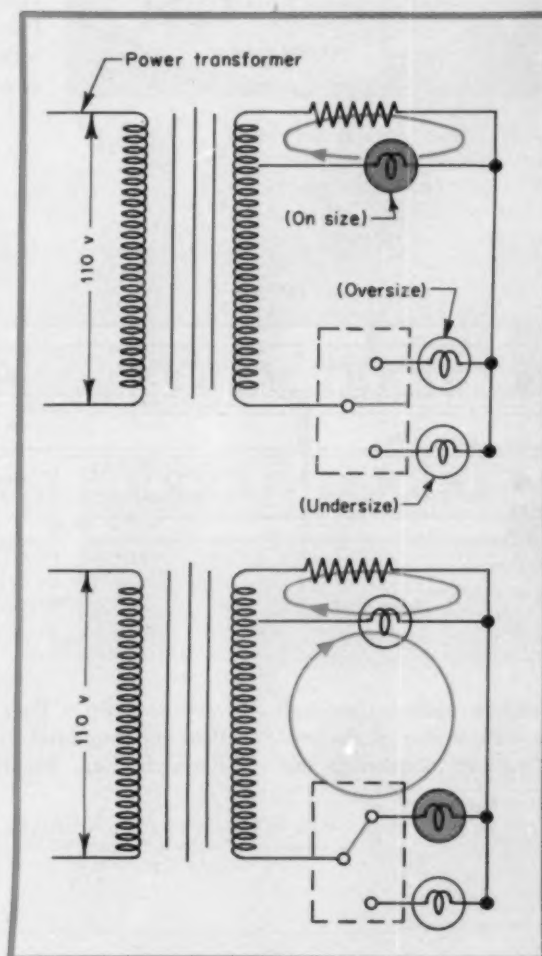


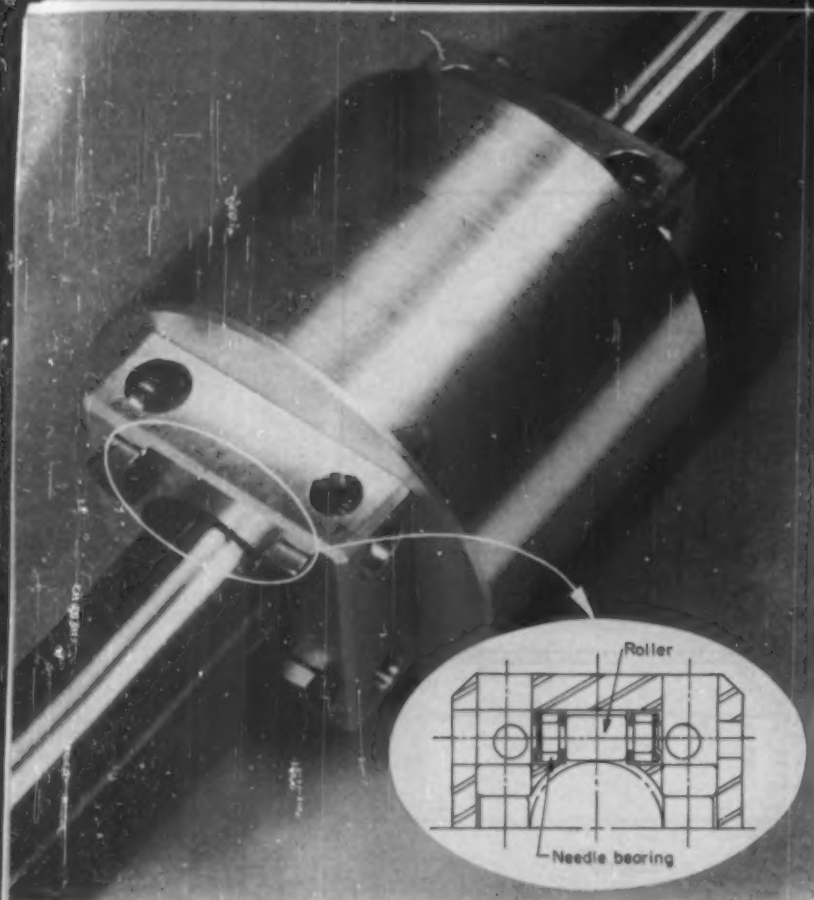
Fluidized particles transfer heat

in a heat-treating tank. The refractory particles have virtually the same physical and thermal properties of a true liquid, but eliminate postcleaning or washing of parts, toxic or corrosive fumes, and abrasion of the parts. Principle employed in a heat process by Industrial Heating Dept., General Electric Co., Shelbyville, Ind.

Opposing currents control lamp

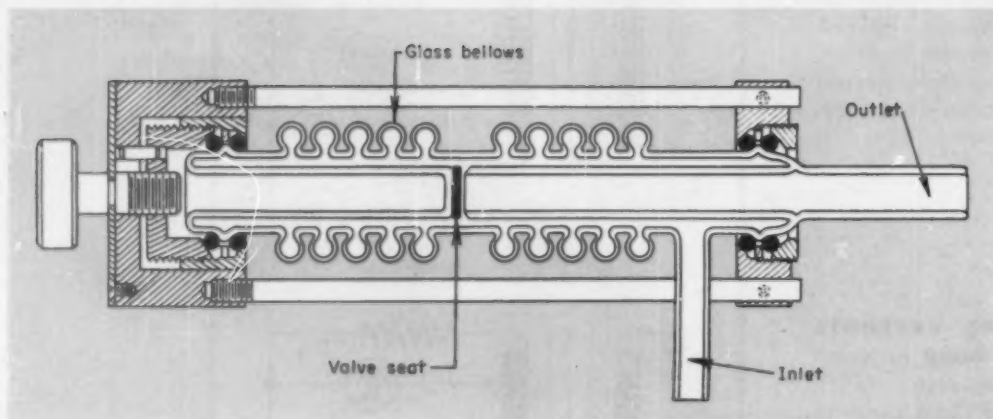
to permit use of a simple SPDT switch in a visual display of indicator measurements. The "on-size" lamp is normally on. However, if a part is under or oversize, the switch lights the corresponding lamp, and opposing currents extinguish the "on-size" lamp. Principle employed in a display device by Hamilton Watch Co., Lancaster, Pa.





SCANNING THE FIELD FOR IDEAS

Crosswise rollers support shaft to permit reciprocating motion of the circular shaft. Four rollers mounted in needle bearings are provided in each collar. Principle employed in roller guide bushing by Zagar Inc., Cleveland.



Flexible glass provides bellows-type seal for a greaseless valve. Deflection of the corrugated glass jacket permits positioning the

valve seat of Du Pont Viton synthetic rubber. Principle employed in a valve by California Research Corp., San Francisco, Calif.

Tolerance Standards

... a system for minimizing notes on engineering drawings

BOTH geometric and dimensional tolerances are necessary on an engineering drawing to fully define a part. For clarity, most geometric and some dimensional tolerances require notes. If many notes are used to control tolerances, drawings can become cluttered, and frequent repetition on similar drawings can be a nuisance.

One way around this problem is to set up an intermediate document or specification that spells out—for specific categories or for specific shops—just what tolerances are expected from “good shop practice.” Here is specific information on such a document, *Manufacturing Tolerance Specification (MTS)*—its organization and its relation to engineering, manufacturing, and quality control.

The MTS is listed in the title block of all production drawings, Fig. 1, as part of the standard drawing format, and thus applies to all manufactured parts. Notes to define tolerances of form are only necessary when tolerances closer than standard are required for proper part function.

ROBERT E. RUCKSTAHL
Manager, Drawing Office

and

GUSTAV A. LARSON
Engineer, Drawing Office

Air Arm Div.
Westinghouse Electric Corp.
Baltimore, Md.

MTS Organization

Following the opening paragraph, Fig. 2, which establishes the scope and purpose of the MTS, the specification is divided into three parts:

A. General—This section states general practices such as “Dimensions and tolerances apply after plating.” and “Dimensions marked REF are not to be inspected.” It also charges the inspection department with the responsibility of applying judgment when checking parts

Fig. 1—Portion of title block. The Manufacturing Tolerance Specification becomes a part of all production drawings.

UNLESS OTHERWISE SPECIFIED		
DIMENSIONS IN INCHES, DO NOT SCALE. TOLERANCES ON		
2 PL. DEC.	3 PL. DEC.	ANGLES
±	±	±
ALSO SEE MFG. SPEC. 300R300		

MANUFACTURING TOLERANCE SPECIFICATION

This specification defines the standard manufacturing tolerances expected from good shop practices at the Air Arm Division and from its subcontractors, and interprets drawing call-outs pertaining to dimensions and tolerances.

The purpose of this specification is to establish the limits of quality acceptable when specific information does not appear on the drawing. The requirements of this drawing shall prevail.

A. GENERAL

1. All dimensions shall be maintained at the International Standard Reference Temperature of 68°F (20°C). It is manufacturer's responsibility to make the necessary conversion for temperature variations.
2. All dimensions and tolerances apply after plating.
3. Any dimension marked "REF" is not an inspection dimension. It is intended as an engineering or manufacturing aid in determining the tolerances that shall apply to a specific part shall be the form of the material from which the part is made. See Section B, paragraph 1. In cases of substitution of material, such as sheet metal for bar stock, the tolerances are originally implied on the drawing shall apply.
5. It is recognized that certain conditions may arise during the course of manufacture which are beyond the control of the manufacturer or the manufacturing department. These conditions, such as economy or limitations of these manufacturing processes being thoroughly considered. There conditions fall under four general categories:

B. SUMMARY OF MANUFACTURING TOLERANCES

MACHINED PARTS

Tolerances for machined parts shall apply only to parts made from materials in plate or bar stock and forgings, or extrusions.

The standard tolerances detailed in this section apply only to machined surfaces.

2. TOLERANCES

A. RADIUS

Internal machined corners, including counter-bore and spotface fillets, not otherwise dimensioned shall have a radius of .02 to .05. Specified radii shall be maintained. Specified shall define a surface such that it falls within the tolerance zone of its radial dimension. All connecting surfaces, plans or curved, shall meet smoothly with the specified surface. See par. C. 1. F.

B. DEBURRING

Edges shall be free of projections or wire edges from a failed surface within the limits of .02. See paragraph C. 1. B.

C. SPOTFACES AND COUNTERBORES

The concentricity of a spotface or counterbore to its central hole shall be such that the hole falls within the dimensional tolerance range. See paragraph C. 1. A.

D. MACHINE TOOL CENTRIES

Holes are permissible unless otherwise noted.

E. HOLES

Maximum permissible taper of a hole, defined as the difference between the largest and smallest diameter is .001 per inch provided it falls within the dimensional tolerance range. See par. C. 1. Q.

SHEET MATERIAL PARTS

Tolerances for sheet material parts shall apply only to parts made from materials in sheet form up to .249 thick.

The standard tolerances detailed in this section apply only to drill parts in flat, drawn, or bent up form.

Bend radii up to and including .125 shall be held to $\pm .010$; over .125 shall be held to $\pm .03$. Internal corners shall be maintained. Specified radii shall have a minimum radius of .06 $\pm .01$ unless otherwise noted.

Spotfaces and counterbores, unless otherwise specified shall have a fillet radius of .02 to .05.

A maximum projection of .003 is permissible for a spotface or counterbore. The contour of the edge must be within the limits of .003 projection and a chamfer of .020 $\pm .020$.

The concentricity of a spotface or counterbore to its central hole shall be such that the hole falls within the dimensional tolerance range. See section C, par 2 A.

Holes are not permitted unless otherwise noted.

Punched holes shall be measured from the entrance side only. Measurements shall be made before spotfacing, counter boring or counter sinking operation.

a. During manufacturing processes such as heat treating, dip brazing, wiring, welding, etc., conditions arise on certain parts and/or assemblies such that the tolerances cannot be established and, therefore, the tolerances specified herein do not apply. In these cases, tolerances shall be established and maintained and added to the drawing where practical.

b. Drill and/or fabricated parts that lack stability (filmy sheet metal, light or thin gages, etc.) may not meet their specified tolerance requirements prior to assembly or installation.

c. Drill and/or fabricated parts may exceed their specified tolerances at a given stage of the manufacturing process but will meet the specified tolerances after subsequent operations are performed as delineated on other drawings.

d. Drill and/or fabricated parts may have surface imperfections such as burrs, score marks, die marks or flaws produced by manufacturing process and/or routine handling.

In all cases falling under these four categories, quality control shall have the responsibility to exercise the necessary judgment to determine the acceptance or rejection of the parts based on the size and the location of the item or the "as found" position if applicable. Items should be rejected only when they do not meet the intent of this specification, the applicable drawings and customer specifications and standards.

When necessary quality control should consult with the engineering department before reaching their decision.

FABRICATED PARTS
NON-PERMANENTLY
FASTENED

Tolerances for fabricated parts—non-permanently fastened shall apply only to parts which are joined or assembled by means of bolts, screws, and nuts.

Operations performed on assemblies of machined parts shall meet tolerances required on machined parts; operations performed on assemblies of sheet metal parts shall meet tolerances required on sheet metal parts; operations performed on assemblies of machined and sheet metal parts shall meet tolerances required of sheet metal parts.

Not applicable.

See paragraph B. 1. above.

See paragraph B. 1. above.

See paragraph B. 1. above.

See paragraph B. 1. above.

FABRICATED PARTS
PERMANENTLY
FASTENED

Tolerances for fabricated parts—permanently fastened shall apply only to machined or sheet metal parts which are joined or assembled by means of such processes as welding, brazing, soldering and riveting.

Operations performed on assemblies of machined parts shall meet tolerances required on machined parts; operations performed on assemblies of sheet metal parts shall meet tolerances required on sheet metal parts; operations performed on assemblies of machined and sheet metal parts shall meet tolerances required of sheet metal parts.

Welded external corners, when noted "Grind to Contour", shall be a faired surface ungent to the radius of the parent metal. See paragraph C. 3. A.

See paragraph B. 1. above.

See paragraph B. 1. above.

See paragraph B. 1. above.

See paragraph B. 1. above.

MANUFACTURING
TOLERANCE
SPECIFICATION

WESTINGHOUSE ELECTRIC CORPORATION
AIR ARM DIVISION
BALTIMORE, MD., U.S.A.

DWG. NO.

300R300

SHEET

2

REV.

Fig. 2—Manufacturing Tolerance Specification, sheets 1 and 2.

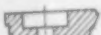
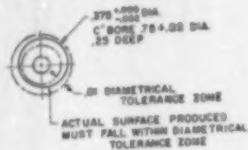
119

C. CLARIFICATION OF TOLERANCES

1. MACHINED PARTS

a. Surfaces and Counterbores

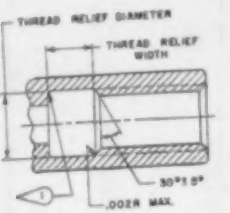
1. The concentricity of a surface or counterbore to 40 counter hole shall be such that the surface produced falls within the dimensional tolerance range.
2. A surface is an axis machined sufficiently to provide a working surface for a hole, nut, washer, or similar item.
3. A counterbore is used when sufficient depth is needed to provide a specific clearance for latching hardware.



b. Screw Threads

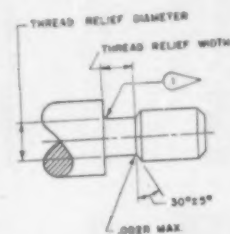
1. Screw threads shall be produced according to ASA B1.1 Unified and American Standard Threads.
2. The length of thread dimensional on the drawing is to be occupied by fully formed threads. The length otherwise specified, when only one dimension is shown, shall be interpreted as the gaging length excluding incompletely formed threads. The length accepted by incompletely formed threads, when not dimensioned, may vary according to the method of manufacture, but is limited to 3 thread pitches maximum.
3. Internal Screw Threads
 - a. The entrance end of internal threads shall be chamfered $100^\circ \pm 10^\circ$ to the major diameter $\pm .01$. The entrance end is defined as the end manufacturing more or closer to outer diameter.
 - b. Wire edges or projections on the far side of a tapped hole shall be removed.
 - c. When the thread is produced in a turn hole, a chamfering angle of 60° to 90° is permissible providing the full thread depth is greater than 1/2 the major diameter.

show the major diameter.
d. The fillet radii and chamfer shall be as follows:



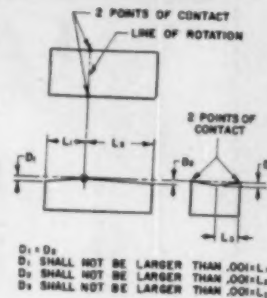
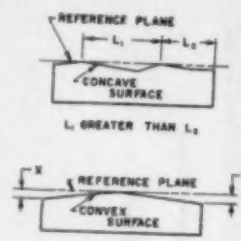
4. External Screw Threads

a. The fillet radii and chamfer shall be as follows:



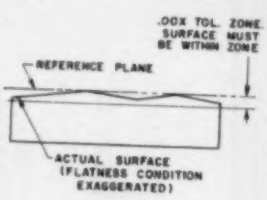
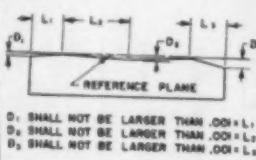
MANUFACTURING TOLERANCE SPECIFICATION	WESTINGHOUSE ELECTRIC CORPORATION	DWG. NO.	REV.
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the same distance from it, or a true plane that would be parallel to such a plane.



1. When the notation "FLAT WITHIN .001" is called for on the drawing it shall be interpreted as follows:

2. The standard tolerance for flatness shall be interpreted as follows:



g. Alignment of Surfaces

1. When a drawing indicates 2 or more machined surfaces to be in the same plane, the finished surfaces, unless otherwise specified, shall be in alignment with each other .001 per inch with respect to a reference plane.

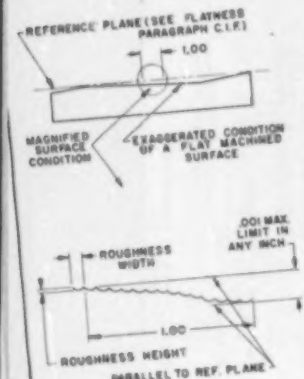
The reference plane shall be determined on the assumption that the intermediate surfaces form a continuous surface. The measurement for alignment shall

In the case of contact between the reference surface and surface at three points, the two points that are the greatest distance shall be used as an axis of rotation and the reference plane rotated to equalize the distance from the reference plane to the surface.

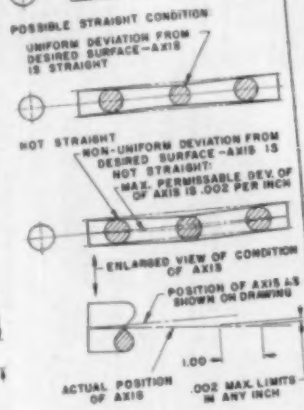
MANUFACTURING TOLERANCE SPECIFICATION	WESTINGHOUSE ELECTRIC CORPORATION	DWG. NO.	REV.
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c. Workpiece

1. The maximum permissible waviness shall be .001 per inch. It shall be applied to each inch only. Note in figure that roughness is superimposed on waviness and waviness is superimposed on flatness.



AS SHOWN ON DRAWING:



c. Twist

1. Twist is the angular rotation of a cross section of a member about its axis or a line parallel to its axis. Commercial tolerances shall apply whether the part is machined or not.

f. Flatness

1. The deviation from flatness of machined surface shall be .001 per inch measured with respect to a reference plane.

The term "reference plane" shall mean that true plane which will rest on the actual surface in such a manner that the extreme points of contact with the surface upon the greatest diameter, or a true plane that would be parallel to such a plane. However, if the actual surface is convex without any valleys, the "reference plane" shall be that true plane which will rest on the high point of the actual surface in such a manner that the two lowest points are

that do not meet tolerances because of conditions which are beyond the ability of the engineer to anticipate or the manufacturing department to prevent.

B. Summary of Manufacturing Tolerances—This section, Fig. 2, spells out the specific geometric tolerances and standard values that can be expected from good shop practices. Each item is defined under each of four categories: 1. Machined parts. 2. Sheet-material parts. 3. Fabricated parts, nonpermanently fastened. 4. Fabricated parts, permanently fastened.

C. Clarification of Tolerances—This section, Fig. 3, interprets the intent of each tolerance and standard value and spells out the form of a specific note to be used on a drawing when something better than standard is functionally required. Table 1 lists the items included in this section.

MTS Development

The MTS was developed by a committee made up of manufacturing, quality control, engineering, and drafting personnel. The committee established geometric tolerances and standard values by agreement on the intent or interpretation of each item considered. Disagreements over what constituted a reasonable value were settled by running tests under production conditions. Several items, however, could

2. The standard is also applicable to torus cylindrical parts. It shall not be confused with lack of straightness. In the case of torus cylindrical parts roughness is superimposed on waviness and waviness is superimposed on straightness of an element.

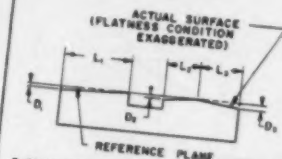
d. Straightness

1. Straightness is a condition where the axis or a line parallel to the axis does not deviate from a straight line more than .001 per inch when checked in the "as used" condition. The standard must be applied for each inch and cannot be added cumulatively and applied against the whole part.

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be made independently of other deviations such as parallelism, waviness, and surface finish. When any one of these features must be considered, the average of most first be established from the reference plane alignment must be measured from the reference plane to any of the surfaces shown on the drawing by a common dimension, or as mentioned above, when other conditions exist the measurement shall be from the reference plane to the mean of the other deviations.

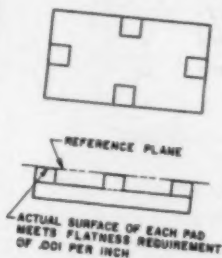
2. Alignment of Two Surfaces.



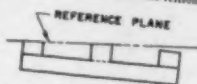
3. Alignment of 4 Surfaces.

Two cases arise:

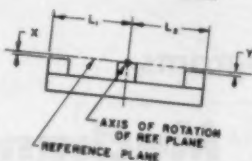
Case 1—All 4 surfaces touch the reference plane



Case 2—3 surfaces touch the reference plane.



In order to check the alignment of surfaces, two points must be used as an axis of rotation and the reference plane rotated to equalize the distance from the reference plane to the other two points.



In order to meet the standard of alignment "X" must equal "Y"; "X" shall not be greater than .001 x L1, and "Y" shall not be greater than .001 x L2, and L1 and L2 are the perpendicular distances from the axis of rotation to the surfaces in question.

4. The tolerance, where functional requirements call for a better than standard value, is spelled out on the drawing as "SURFACES TO BE IN ALIGNMENT WITHIN .001 TIR"



5. Surfaces shown in the same plane, but dimensioned separately on the drawing will not be confined by this standard.

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Fig. 3 — Typical Clarification-of-Tolerance sheets for machined parts.

Table 1—Items under "Clarification of Tolerances"

Machined Parts

- C1A Spotface and counterbores
- B Screw threads
- C Waviness
- D Straightness
- E Twist
- F Flatness
- G Alignment of surfaces
- H Squareness of two surfaces
- I Squareness of a surface and a hole
- J Intersection of holes
- K Parallelism of two surfaces
- L Parallelism of surface and hole
- M Parallelism of two holes
- N Alignment of holes
- O Holes common to center line
- P Radii
- Q Holes
- R Deburring
- S Surface finish

Sheet Material Parts

- C2A Spotface and counterbores
- B Screw threads
- C Flatness
- D Alignment of surfaces
- E Squareness of two surfaces
- F Intersection of holes
- G Parallelism of two surfaces or edges
- H Alignment of holes
- I Holes common to center line

Fabricated Parts

- C3A Radii
- B Screw threads
- C Alignment of surfaces

not be settled in such a straight-forward manner because of their nebulous nature. The discussion of these items resulted in a statement that recognizes the judgment factor of the inspection function:

"It is recognized that certain conditions may arise during the course of manufacturing which are beyond the ability of the engineer to anticipate or the manufacturing department to prevent—economy or limitations of the manufacturing process being thoroughly considered. These conditions fall under four general categories . . . (Fig. 2, paragraph A5). In all cases falling under these four categories, quality control shall have the responsibility to exercise the necessary judgment to determine the acceptance or rejection of the parts . . ."

One of the problem areas considered which eventually resulted in this statement was the tolerance applied to the flatness of a bent-up sheet-metal part: What flatness value can be expected from good shop practice? How can a single value be applied? Flatness depends not only on fabrication practice, but also on the material, the configuration of the part, and the severity of heat treatment applied. The problem was resolved by establishing the value for a simple chassis and requesting that quality control recognize that this value would be exceeded at times due to extenuating circumstances and that judgment must be used to determine acceptability.

Constructing acceleration diagrams for **Space Mechanisms**

Finding velocities and accelerations of three-dimensional mechanisms can be a complex problem. However, the fundamental graphic methods for analyzing motion in plane mechanisms can be extended to do the same job in space mechanisms. Here are detailed examples to show how it's done.

W. G. WOOD

Dept. of Mechanical Engineering
Imperial College of Science and Technology
University of London
London, England

MOTIONS in plane mechanisms are often resolved graphically by velocity and acceleration-image diagrams. The same principles—coupled with orthographic projection—can be used to analyze space mechanisms. No new principles are involved, although some of the theorems, written in terms of plane mechanisms, must be interpreted more generally.

Three mechanisms are analyzed here; all are essentially simple, but their solutions show the treatment of some of the typical problems associated with determining motion in space mechanisms.

Usually, a plan and elevation are required for each of the

Nomenclature

A = Linear acceleration*
 V = Linear velocity*
 Ω = Angular velocity

Subscripts

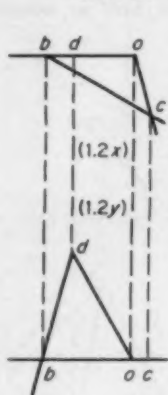
n = Normal component†
 t = Tangential component†

*Measured in a co-ordinate system attached to the fixed link of the mechanism.

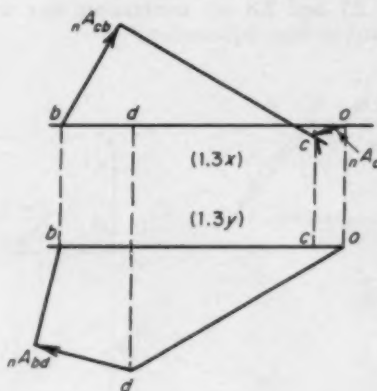
†For clarity, subscripts n and t are used before the A or V . Thus, ${}_nA_{AB}$ = the normal component of ($A_A \rightarrow A_B$).

Example One

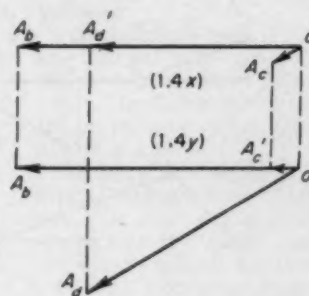
... a simple five-bar chain with four turning pairs and one spherical pair. Links BC and OC effectively move in one plane, and links DB and OD in another. The two planes are at right angles.



Velocity Image



Acceleration Image



Acceleration Vector

Velocity Diagram

1. Starting from an arbitrary base line, Fig. 1.2y, draw od , a directed line (from o to d), to some convenient scale, perpendicular to OD in 1.1y. Draw db perpendicular to DB .

2. In 1.1y, B and C move, with respect to O , in one plane (actually parallel planes, here seen edgewise). Hence, o , b , and c lie on a horizontal line in 1.2y, and point b is fixed.

3. In 1.1x, D and B move in a plane DB (here seen edgewise). Draw a horizontal line in 1.2x and project o , d , and b to this line from 1.2y.

4. In 1.2x, draw bc and oc perpendicular to BC and OC . This fixes point c .

5. Project point c down to 1.2y, completing the velocity diagram.

Acceleration Diagram

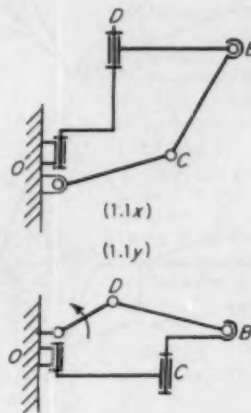
1. Fix point o in horizontal lines in Fig. 1.3x and 1.3y. Acceleration images of D and B will lie on this line in 1.3x, since D and B move in a plane which is seen edgewise in 1.1x. For similar reasons, acceleration images of B and C will lie on the horizontal line in 1.3y.

2. Draw a unit vector $od = (V_d)^2/(OD)$ in 1.3y, parallel to OD in 1.1y. Assuming the angular velocity of OD is constant, this fixes d in both views.

3. In 1.3y, draw $nb_{bd} = (V_{db})^2/(BD)$. Draw a line perpendicular to this which intersects the horizontal line at b . Project b into 1.3x.

4. In 1.3x draw $na_{cb} = (V_{bh})^2/(BC)$ directed parallel to CB , and $na_c = (V_c)^2/(OC)$ directed along CO . Draw perpendicular lines to these acceleration vectors. The intersection of the perpendiculars determines point c .

5. Project c into 1.3y. The acceleration vectors for points D , B , and C are shown in 1.4x and 1.4y. The "prime" notation is used to designate vectors not shown as true lengths.



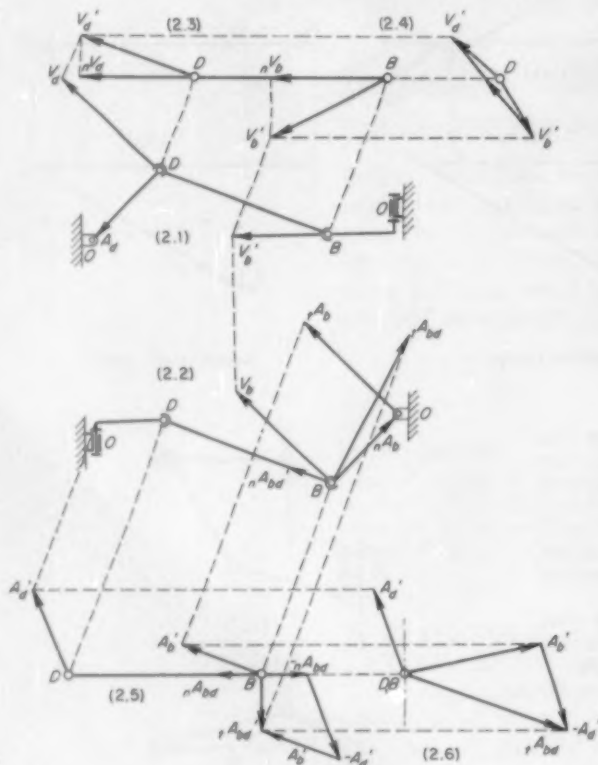
Configuration

velocity image and acceleration-image diagrams, corresponding to the plan and elevation of the configuration diagram of the mechanism. Where a true view of a line is not obtained in the configuration diagrams, or where oblique motions occur, partial views are needed. True views of the moving parts are necessary so that normal components of acceleration may be set off and projected to other views. Tangential acceleration is de-

Example Two

... a simple four-bar chain with two turning pairs and two spherical pairs. Cranks OD and OB turn in perpendicular planes and are connected by the coupler DB.

For this example, most of the construction can be done on the configuration diagram. Parts 2.7 and 2.8 are unnecessary but are shown here as summaries of velocity and acceleration information.



Velocities

1. Draw a unit vector V_d in Fig. 2.1 and project into 2.3 and 2.4. Draw nV_d and nV_b in 2.3. These values are equal because projections of the velocities of all points on a line in motion are equal.

2. Project a point on the path of B in 2.2 (for convenience, use the tip of V_b , the length of which is, as yet, unknown) into 2.1, 2.3, and 2.4, to give the path of B in each of these views.

3. In 2.3, project nV_b into the

path of B. Thus, V_b' , when projected through 2.1 into 2.2, results in V_b . Since all velocities are now known, 2.7 can be constructed. (Note that V_{db} is the line joining the tips of vectors V_d' and V_b' in 2.4.)

Accelerations

1. Assuming that V_d is constant, draw A_d in Fig. 2.1 and project through 2.2 into 2.5 and 2.6.

2. Evaluate $nA_{bd} = (V_{bd})^2/(DB)$ and construct in 2.5.

3. Evaluate $nA_b = (V_b)^2/(OB)$

and construct in 2.2.

4. In 2.5, the plane containing crank OB is seen edgewise (in line BA_b'). Hence, the total acceleration of B must, in this view, lie in this line (magnitude not yet known).

5. From the relation $A_{bd} = A_b \rightarrow A_d$, which is found from

$$tA_{bd} \rightarrow nA_{bd} = A_b \rightarrow A_d$$

it is apparent (in 2.5) that the paths of A_b and tA_{bd} are known, and the vectors nA_{bd} and A_d' are known. Construct the polygon

$$tA_{bd} = A_b' \rightarrow A_d' \rightarrow nA_{bd}$$

and obtain tA_{bd}' and A_b' .

6. Project A_b' from 2.5 to 2.2, and there, add vector tA_b to nA_b so that

$$A_b = nA_b \rightarrow tA_b$$

Hence, tA_b is determined.

7. A true view of tA_{bd} can be drawn in 2.6 by constructing A_d' and A_b' in this view and employing $A_{bd} = A_b \rightarrow A_d$.

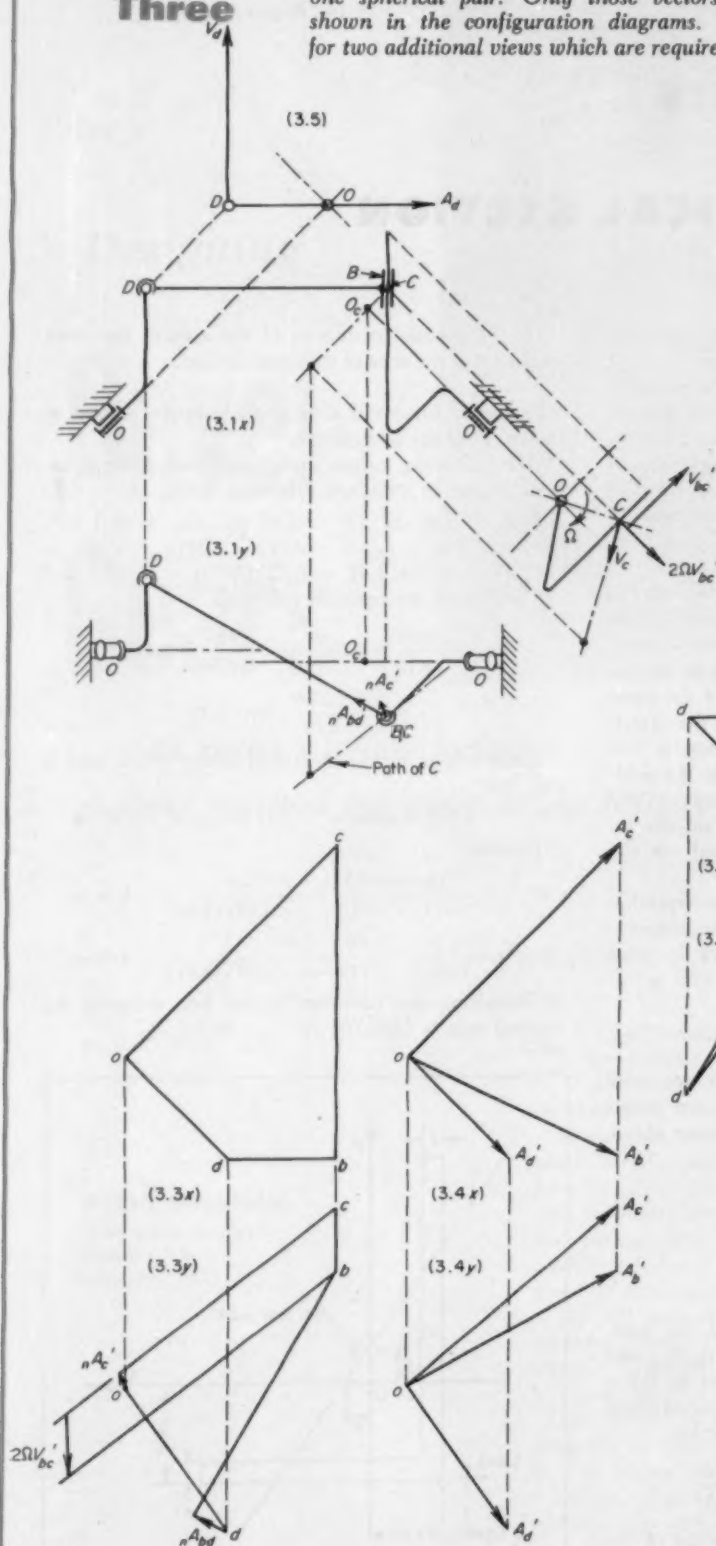
8. Thus, all accelerations are known, and A_b and A_d can be drawn in plan and elevation in 2.8.

terminated by projecting a line representing the path of the required point into each view.

Where relative sliding occurs in spatial motion, only a component of the relative sliding velocity will, in general, undergo rotation, and the Coriolis acceleration resulting from such motion depends on this rotated component and the angular velocity of rotation.

Example Three

... a four-bar chain with two turning pairs, one turning and sliding pair, and one spherical pair. Only those vectors necessary to illustrate the analysis are shown in the configuration diagrams. Layout is similar to Example 1, except for two additional views which are required for this solution.



Velocities

1. Draw a unit vector V_d in true view 3.5, and project into 3.1x and 3.1y. Draw od in 3.2x and 3.2y.
2. In 3.1y, B must move (relative to D) perpendicular to link DB . Draw path db in 3.2y.
3. Project a point on the path of C from 3.6 through 3.1x into 3.1y. Draw path oc in 3.2y. Because no relative velocity between B and C appears in 3.1y, b and c coincide in 3.2y.
4. Point c rotates about center O_c in 3.1x and B must move (relative to D) in the plane seen edgewise as DB in the same view. Draw paths db and oc in 3.2x.
5. Project b and c from 3.2y to 3.2x, completing the velocity diagram.

Accelerations

1. Assuming that V_d is constant, draw unit vector A_d in Fig. 3.5 and project into 3.1x and 3.1y. Draw od in 3.3x and 3.3y.
2. From the velocity diagram, obtain V_c' in 3.1x and project to 3.6 as V_c .
3. Draw nA_c in 3.6 and project through 3.1x into 3.1y (vector directed toward center of rotation O_c) as nA_c' .
4. Draw nA_c' in 3.3y and a line from the tip of it parallel to the path of C in 3.1y.
5. In 3.1x, C moves in a plane seen edgewise as CO_c . Draw path oc in 3.3x.
6. Evaluate nA_{bd} in 3.1y and plot in 3.3y, together with a line from its tip, drawn perpendicular to line of DB .
7. In 3.1x, B moves (with respect to D) in the plane seen edgewise as DB . In 3.3x, draw a horizontal line through d . Point b must lie on this line.
8. In 3.1x, draw V_{bc} and project into 3.6 as V_{bc}' . This component rotates at angular velocity $\Omega = V_c/(OC)$ in 3.6. The Coriolis acceleration, $2\Omega V_{bc}'$, can be projected through 3.1x into 3.1y and plotted in 3.3y as an offset from the line of c , producing the line on which b must lie.
9. Project b from 3.3y to 3.3x.
10. The relative sliding acceleration between B and C does not show in 3.1y and 3.3y, and the Coriolis component is not seen in 3.1x and 3.3x. Thus, in 3.3x, c must lie vertically above b . Project c from 3.3x into 3.3y, completing the acceleration diagram. The plan and elevation of A_d , A_b , and A_c are shown in 3.4.

How to find the NEUTRAL AXIS of an UNSYMMETRICAL SECTION

DETERMINING the position of the neutral axis is an important step in the solution of many beam-design problems. This article presents a quick, accurate method for determining the neutral axis of an unsymmetrical section. The method simplifies considerably the stress analysis of irregular machine parts by bypassing the calculations for the inclination of the principal axes, and the need to refer properties and dimensions to the rotated axes.

When a member is subjected to axial loads and bending moments, it is usually assumed that if the cross sections were initially plane, they remain plane after bending (Bernoulli's assumption). Consequently, the strains at various points in the cross section are directly proportional to the distances of the same points from the neutral axis. As long as the elastic limit is not exceeded, the stress distribution is also linear. Within the range of elastic behavior the position of the neutral axis does not depend on the magnitude of the applied loads, but only on the location of the resultant external load, and on the geometry of the section.

The neutral axis can be represented by an equation using its intercepts, a and b , on two rectangular coordinate axes, with origin at the centroid of the cross section. The equation of the neutral-axis line is

$$\frac{x}{a} + \frac{y}{b} = 1$$

The following expressions for a and b are valid during an elastic-stress response. They are based on the assumptions that plane sections remain plane, and that conditions of equilibrium prevail:

$$a = \frac{r_{xx}^2 r_{yy}^2 - r_{xy}^2}{e_y r_{xy}^2 - e_x r_{xx}^2}$$

$$b = \frac{r_{xx}^2 r_{yy}^2 - r_{xy}^2}{e_x r_{xy}^2 - e_y r_{yy}^2}$$

where e_x and e_y are the eccentricities of the load, measured along the x and y axes, and r_{xx} , r_{yy} , and r_{xy} are the radii of gyration with respect to the x axis, y axis, and origin. These are computed from the geometrical properties of the cross section:

$$r_{xx}^2 = \frac{I_{xx}}{A}; \quad r_{yy}^2 = \frac{I_{yy}}{A}; \quad r_{xy}^2 = \frac{I_{xy}}{A}$$

where I_{xx} and I_{yy} are the moments of inertia of the area of the cross section about the x and y axes.

I_{xy} is the product of inertia of the area of the cross section; A is the area of the cross section.

Example: An 8 x 6 x 1/2 angle supports a load as shown. Find the neutral axis.

The following values are determined from equations found in standard reference books: $A = 6.75$ in.²; $\bar{X} = 1.47$ in.; $\bar{Y} = 2.47$ in.; $I_{xx} = 44.3$ in.⁴; $I_{yy} = 21.7$ in.⁴; $I_{xy} = -A(x - t/2)(y - t'/2) = -(1.47 - 0.25)(2.47 - 0.25)(6.75) = -18.3$ in.⁴

Then, from the equations shown,

$$r_{xx}^2 = \frac{44.3}{6.75} = 6.56; \quad r_{yy}^2 = \frac{21.7}{6.75} = 3.21;$$

$$r_{xy}^2 = \frac{-18.3}{6.75} = -2.71$$

Load eccentricities, measured along the x and y axis, are

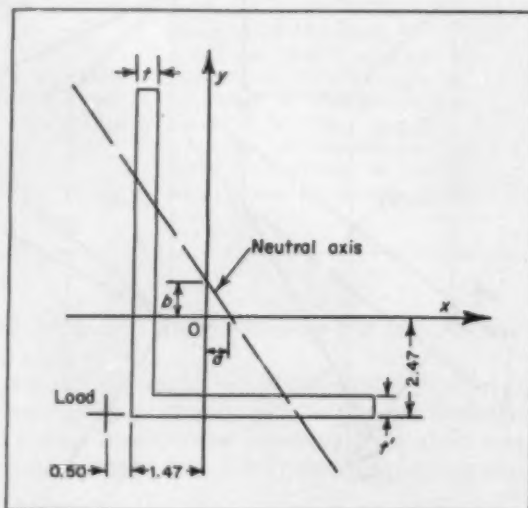
$$e_x = -(1.47 + 0.50) = -1.97 \text{ in.}; \quad e_y = -2.47 \text{ in.}$$

Finally,

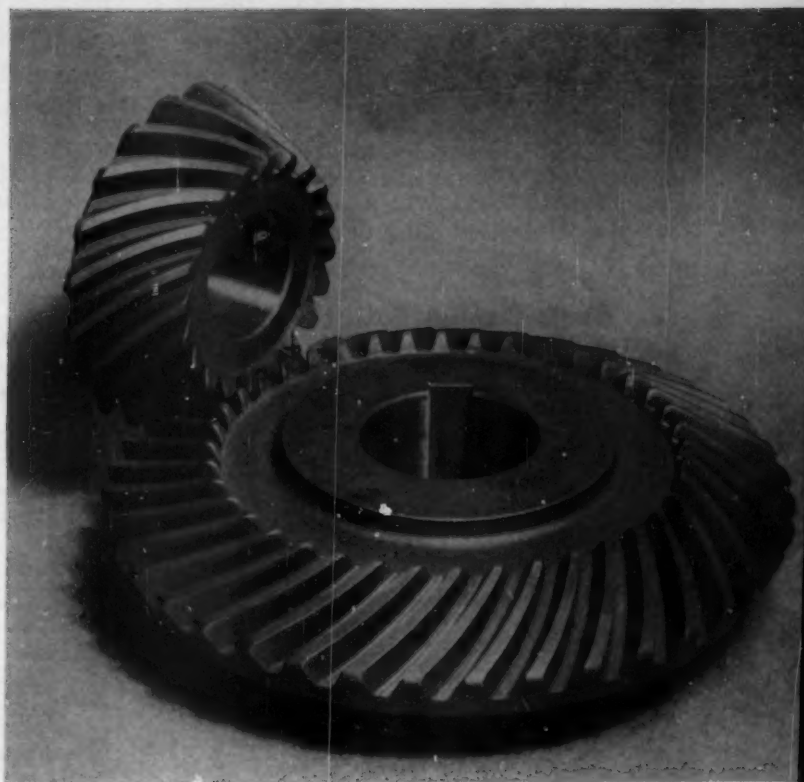
$$a = \frac{(6.56 \times 3.21) - (2.71)^2}{(-2.47)(-2.71) - (-1.97)(6.56)} = 0.70 \text{ in.}$$

$$b = \frac{21.06 - 7.34}{(-1.97)(-2.71) - (-2.47)(3.21)} = 1.03 \text{ in.}$$

Therefore, the equation of the line defining the neutral axis is $(x/0.70) + (y/1.03) = 1$.



Designing Bevel Gears



... to resist surface fatigue:

A new method for preventing failure by pitting

WELLS COLEMAN

Chief Gear Analyst
Gleason Works
Rochester, N. Y.

SURFACE fatigue, breakage, and scoring are the three major types of gear-tooth failure. A well-balanced design requires investigation of all three of these criteria.

In the past, common practice was to design bevel gears to resist pitting and scoring with an empirical formula which states that the load capacity for surface durability is proportional to the square root of the pinion pitch diameter. This formula yielded coarse-pitch gears that were rather lightly stressed and fine-pitch gears that were highly stressed. Gears of 10 DP and finer could not be safely designed by this method. Today it is recognized that a single formula to guard against both pitting and scoring is impractical.

This article presents a new, separate method for designing to resist surface fatigue, or more specifically, the pitting resistance of bevel-gear teeth.

Pitting failures are believed to be caused by sub-surface shear or tension stresses. It has been shown

that there is a specific relationship between these subsurface stresses and fatigue life of bevel-gear tooth surfaces due to pitting. Since contact stress at the tooth surface is proportional to subsurface shear and tensile stresses, contact stress may be used as a criterion for design. The design method presented here is based on this premise.

Basic Design Equations

The basic equation for contact stress in a bevel gear is

$$s_c = C_p \sqrt{\frac{W_t C_o}{C_e} \left(\frac{1}{F d} \right) \left(\frac{C_m C_l}{C_s C_T C_R} \right)} \quad (1)$$

The basic equation for working stress is

$$s_w = \frac{s_{oc} C_L C_H}{C_T C_R} \quad (2)$$

Calculated maximum contact stress must be equal to or less than the working stress:

$$s_c \leq s_w \quad (3)$$

To determine the power capacity of an existing pair of gears, the following power formula may be used:

$$P_{ac} = \left(\frac{s_{oc} d C_H C_L}{C_p C_T C_R} \right)^2 \left(\frac{n_P F}{126,000} \right) \left(\frac{I C_o}{C_e C_m C_l} \right) \quad (4)$$

Design Factors

The factors discussed in this section are used in Equation 1 for maximum contact stress and in Equation 2 for working stress.

Gear Size

Pinion pitch diameter d and face width F . . . required to satisfy the design conditions can be calculated as follows:

$$d^2 F = \frac{126,000 P C_o}{n_P C_e} \left(\frac{C_m C_l}{I} \right) \left(\frac{C_p C_T C_R}{s_{oc} C_H C_L} \right)^2 \quad (5)$$

or

$$d^2 F = \frac{2 T C_o}{C_e} \left(\frac{C_m C_l}{I} \right) \left(\frac{C_p C_T C_R}{s_{oc} C_H C_L} \right)^2 \quad (6)$$

By trial, a satisfactory solution may be obtained in which F should not exceed one-third of the cone distance. For right-angle pairs,

$$d^3 = \frac{(d^2 F)}{0.15 \sqrt{1 + m_G^2}} \quad (7)$$

Materials

Elastic coefficient C_p . . . for bevel gears with localized tooth contact is

$$C_p = \sqrt{\frac{3}{2\pi} \left(\frac{1}{\frac{1 - \mu_P^2}{E_P} + \frac{1 - \mu_G^2}{E_G}} \right)} \quad (8)$$

Table 1 gives values of the elastic coefficient and the modulus of elasticity for common combinations of bevel-gear materials.

Load

Transmitted tangential load W_t . . .

is calculated directly from the power or torque transmitted:

$$W_t = \frac{126,000 P}{d n_P} = \frac{2 T}{d} \quad (9)$$

Nomenclature

C_l	= Surface-condition factor
C_H	= Hardness-ratio factor
C_L	= Life factor
C_m	= Load-distribution factor
C_o	= Overload factor
C_p	= Elastic coefficient
C_R	= Factor of safety
C_s	= Size factor
C_T	= Temperature factor
C_e	= Dynamic factor
d	= Pinion pitch diameter, at outer end of tooth, in.
E_P, E_G	= Young's modulus of elasticity for materials of pinion and gear, respectively
F	= Face width, in.
I	= Geometry factor
L_{OP}	= Required equivalent life in pinion cycles at maximum torque
L_H	= Required total life in hours
m_G	= Gear ratio
N_P, N_G	= Number of teeth in pinion and gear, respectively
n_P	= Pinion speed, rpm
P	= Power to be transmitted, hp
P_{ac}	= Allowable power which may be safely transmitted at pinion speed n_P , hp
s_{oc}	= Allowable contact stress, psi
s_c	= Calculated maximum contact stress, psi
s_w	= Working stress, psi
T	= Pinion torque, lb-in.
v	= Pitch-line velocity, fpm
W_t	= Transmitted tangential load, lb
μ_P, μ_G	= Poisson's ratio for materials of pinion and gear, respectively

Table 1—Elastic Coefficients

Pinion	Gear	Elastic Coefficient, C_p
Steel	Steel	2800
($E = 30 \times 10^6$ psi)		
Cast iron	Cast iron	2250
($E = 19 \times 10^6$ psi)		
Steel	Cast iron	2450
	or	
Cast iron	Steel	

Maximum tangential load depends upon maximum torque rather than maximum power. Therefore, torque characteristics of the driving motor and the driven apparatus must be considered. Inertia, torsional vibration, and braking forces must be taken into account.

Overload factor C_o . . .
makes allowance for the roughness or smoothness of operation of both the driving and driven units. Many prime movers develop momentary overload torques which are much greater than those determined by the rated power of the prime mover. Table 2 gives suggested values to use as a guide, unless previous experience dictates otherwise. Under extreme conditions much higher factors may be required.

Table 2—Overload Factors C_o *

Prime Mover	Type of Load on Driven Machine		
	Uniform	Medium Shock	Heavy Shock
Uniform	1.00	1.25	1.75
Light Shock	1.25	1.50	2.00
Medium Shock	1.50	1.75	2.25

*For speed-decreasing drives; for speed-increasing drives add $0.01 (N_o/N_p)^2$ to the above factors.

A service factor . . .
is a special factor which has been established by an industry for a specific application. A service factor includes not only the overload factor, but also the life factor and factor of safety. Therefore, if a service factor is used, factors C_o , C_L , and C_R should be omitted from the basic equations.

Dynamic factor C_d . . .
reflects the effects of inaccuracies in the gear teeth. See Fig. 1. Pitch-line velocity is:

$$v = 0.262 \pi n_p d \quad (10)$$

Stress Distribution

Size factor C_s . . .
reflects the influence of size upon the hardenability of a material, and hence, upon surface durability. At present there are not enough data available to evaluate C_s . A factor of unity may be used unless experience dictates otherwise.

Load-distribution factor C_m . . .
allows for relative displacements of the gears from their ideal position. Performance of bevel gears is dependent to a considerable degree upon their alignment under operating conditions. When deflections or displacements are known or can be estimated with reasonable accuracy, the load-distribution factor can be determined from Fig. 2. Otherwise, use Table 3.

Table 3—Load Distribution Factor C_m

Application	Member Straddle-Mounted—		
	Both	One	Neither
General			
Industrial	1.00—1.10	1.10—1.25	1.25—1.40
Automotive	1.00—1.10	1.10—1.25	
Aircraft	1.00—1.25	1.10—1.40	1.25—1.50

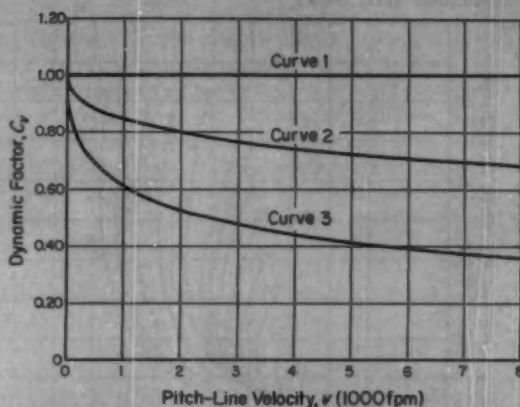


Fig. 1—Dynamic factor C_d . Use curve 1 for bevel gears having proper tooth contact and accurate tooth spacing and concentricity. Use curve 2 for commercial-quality spiral-bevel gears. Use curve 3 for commercial-quality straight-bevel and Zerol bevel gears.

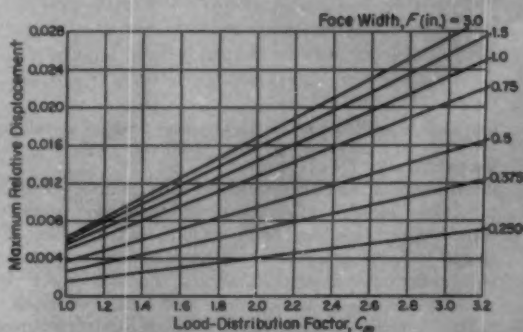


Fig. 2—Load-distribution factor C_m . Displacement refers to either a change in the perpendicular distance between the gear and pinion axes or relative movement of the gear and pinion along the cone element.

It is generally assumed that the tooth contact has been developed to give a suitable pattern in the final mountings under normal operating load. If this assumption does not hold, higher values for the load-distribution factor must be used.

In Fig. 2, use the value of maximum relative displacement, from the position for which the tooth contact is developed, together with the corresponding load. In order to obtain the amount of displacement along the cone element, multiply the axial displacement by the cosine of the pitch angle.

When using Table 3, use the larger tabular value unless it is known that the mountings will be carefully designed for maximum rigidity.

Surface-condition factor C_f . . .
depends on surface finish as affected by cutting, lapping, grinding, shot peening, run-in, etc. It also depends on preliminary surface treatment, such as Lubrizing, copper plating, etc. There are insufficient test data available at present to establish values. Therefore, a value of unity may be used,

DESIGNING BEVEL GEARS

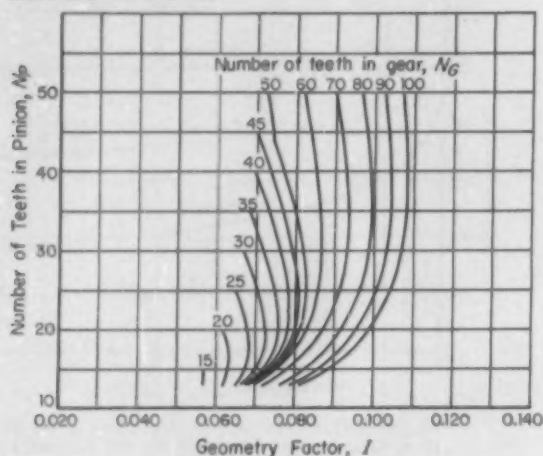


Fig. 3—Geometry factor I for Coniflex straight bevel gears and Zerol bevel gears operating at 90-deg shaft angle.

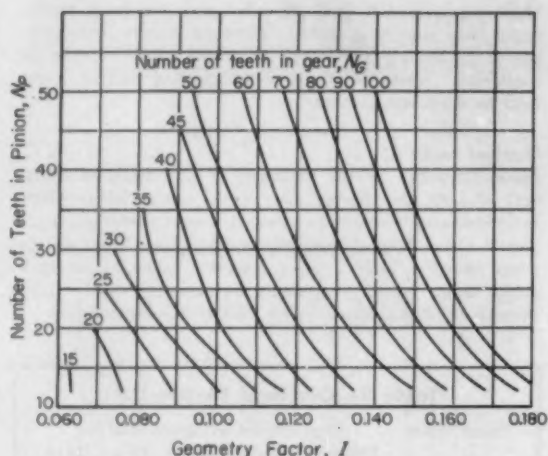


Fig. 4—Geometry factor I for spiral bevel gears with 35-deg spiral angle operating at 90-deg shaft angle.

provided first-class gear-manufacturing practice is followed.

Geometry factor I . . .

incorporates relative curvature between mating tooth surfaces, load location, load sharing, effective face width, and inertia effects resulting from a low contact ratio. This geometry factor is based on the surface curvatures at the point where the contact stress is a maximum rather than at the pitch line, as is customary with other gear types.

Fig. 3 gives geometry factors for generated (crowned) Coniflex straight-bevel gears and Zerol bevel gears operating at 90-deg shaft angle when designed according to AGMA 208.01, "System for Straight Bevel Gears" or AGMA 202.02, "Zerol Bevel Gear System." Fig. 4 gives geometry factors for generated (crowned) spiral bevel gears with 35-deg spiral angle operating at 90-deg shaft angle when designed according to AGMA 209.01, "System for Spiral Bevel Gears."

Working Stress

Allowable contact stress s_{ac} . . .

is based upon the properties of the material. Table 4 gives nominal values for commonly used gear materials.

Life factor C_L . . .

is given by Fig. 5. Because pitting is a fatigue phenomenon, life of a pair of bevel gears is dependent upon the stress level at which the gears operate. Since contact stress on gear and mating pinion will be equal, the life factor depends upon the required pinion life.

In cases where the load varies, the designer may wish to determine the equivalent life at maximum torque. One suggested formula which has been widely used is based on cumulative damage.

$$L_{CP} = 60 L_H \left[k_1 n_{P1} + k_2 n_{P2} \left(\frac{T_2}{T_1} \right)^9 + k_3 n_{P3} \left(\frac{T_3}{T_1} \right)^9 + \dots \right] \quad (11)$$

where k_1, k_2, k_3, \dots = per cent of the time at torque loads T_1, T_2, T_3, \dots ; $n_{P1}, n_{P2}, n_{P3}, \dots$ = pinion speed in

Table 4—Allowable Contact Stresses

Material	Heat Treatment	Min. Surf. Hardness Brinell	Rockwell C	Contact Stress s_{ac} (psi)
Steel	Carburized (case-hardened)	625	60	250,000
Steel	Carburized (case-hardened)	575	55	200,000
Steel	Flame or induction hardened	500	50	190,000
Steel	Hardened and tempered	440		190,000
Steel	Hardened and tempered	300		135,000
Steel	Hardened and tempered	180		95,000
Cast Iron	As cast	200		65,000
Cast Iron	As cast	175		50,000
Cast Iron	As cast			30,000

rpm corresponding to torque loads T_1, T_2, T_3, \dots ; T_1, T_2, T_3, \dots = torque loads, where T_1 is maximum torque.

Hardness ratio factor C_H . . .

depends on the gear ratio and relative material hardness of pinion and gear. For gear ratios below 8 to 1, use a value of 1.0. For ratios above 8 to 1 and materials of un-

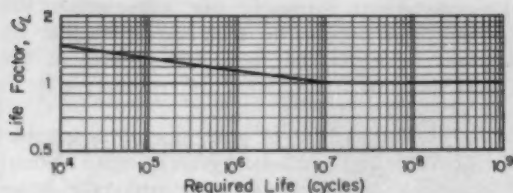


Fig. 5—Life factor C_L . It is dependent upon the number of cycles required of the pinion.

equal hardness, it may be necessary to give further consideration to this factor.

Temperature factor C_T . . . can be unity under normal conditions. For high-temperature application above 200 F, special consideration should be given to this factor.

Factor of safety C_R . . . offers the designer an opportunity to design for maximum safety or, in some instances, to design for a calculated risk. See Table 5. The term, failure, in Table 5 does not mean an immediate failure under the applied load, but rather a shorter life than the minimum specified.

Table 5—Factors of Safety

Application Requirements	Factor of Safety, C_R
Maximum safety	1.25 or higher
Fewer than 1 failure in 1000	1.0
Fewer than 1 failure in 3	0.8

Applying the Pitting Formula

Where space and weight are at a premium, one of the major problems in arriving at a satisfactory gear design is the compilation of accurate data on loads, speeds, and environmental factors. Too often these factors are all but unknown.

Loads: The usual approach is to use the rated motor horsepower or peak motor torque in determining the load. Peak motor torque may be safe, but is not necessarily a reasonable assumption. Some prime movers produce considerable torque variation. Frequently, the gears will never be subjected to the maximum input torque. In certain applications the probability of attaining maximum torque is very low. Then, designing for a calculated risk may be in order.

Speeds: Operating speed may be important. High operating speeds result in a rapid build-up of stress cycles. In addition high operating speeds demand more accurate gears to reduce dynamic overloads which may be superimposed on the already high transmitted loads. Also, speeds and corresponding loads must be analyzed simultaneously and listed.

Overloads: Torque fluctuations in the driving motor or the driven apparatus can cause overloads.

A heavy flywheel on the motor shaft can increase potential torque input momentarily in an application where momentary high output torque is required. External brakes may impose high overloads. Measurement of these transient torques is difficult, since energy absorption may be very small. The most reliable method for checking transient torques is to use strain gages mounted on the input and output gear shafts with a highly sensitive recorder which can record these fleeting changes.

Time Duration: Because the life of a pair of gears is dependent upon duration of the loads, it is important to make an analysis of the drive to determine the length of time the gears will operate at each load. A torque-time graph, Fig. 6, should be prepared. The torque-time curve should be based on a constant speed, and all loads which occur at other speeds should have their time duration adjusted to the assumed speed of the curve.

For example, a pair of gears may normally operate at 2000 rpm. Peak starting torque occurs at a speed of 50 rpm and duration is actually 5 sec. If the torque-time curve has been prepared for a speed of 2000 rpm, the time duration of the starting torque will be $5(50)/2000 = 0.125$ sec.

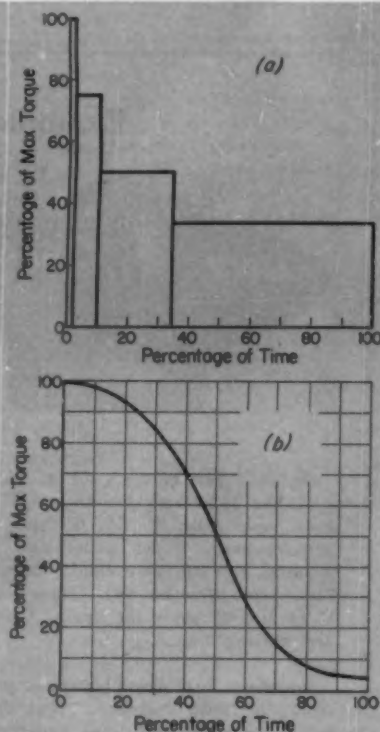


Fig. 6—Typical torque-time (a) step chart and (b) curve.

Normally the torque-time curve is plotted as torque in pound-inches or pound-feet and time in per cent of the total life of the unit.

Elasticity of the Drive System: Shock loads are

difficult to calculate and measure. Dynamic effects set up in a gear drive depend upon the inertia forces of the driving and driven apparatus and the torsional rigidity of the shafts connecting the various components. If large masses and high accelerations are to be encountered, forces should be analyzed. Effects of torsional rigidity should also be investigated. A closely coupled gear set with short rigid shafts may transmit a high dynamic overload, whereas a more loosely coupled gear set with long limber shafts may transmit practically no dynamic overload.

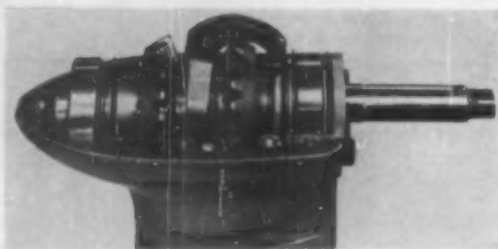
Environmental Factors: Occasionally gears are called upon to operate under unusual environmental conditions. The presence of fresh water, sea water, water vapor, steam, acid or chemical fumes, unusual amounts of dirt, or abrasive particles in the atmosphere surrounding the gear box may lead to premature failure of the gears. Also, extreme conditions of temperature may have an adverse effect on gear life. Most gear drives are designed to operate between 150 F and 200 F. At higher temperatures most lubricants are unstable and the gears themselves approach or may exceed the draw temperature of

the material. At extremely low temperatures the lubricant may congeal to such an extent that no lubricant is present on the tooth surfaces at the time of start-up.

Gear Mountings: Rigid gear mountings are important. With spur and helical gears a certain amount of mounting flexibility may be intentionally introduced to compensate for the effects of deflection under load. With bevel gears this procedure has proven impractical, since the normal deflections due to load add to, rather than to offset, the mounting deflections. It is imperative that the relative position of gear and mating pinion remain nearly constant over the full range of operating loads. Fig. 2 shows the large effect of operating misalignment.

Lubrication: Provision for adequate lubrication is essential. However, pitting tends to increase with an excessive amount of lubricant. Therefore, the problem is to supply a sufficient amount to lubricate and cool the rubbing surfaces to prevent scoring or excessive wear, but not so much as to cause churning which may lead to overheating. With respect to pitting, the lubricant is essentially a coolant to prevent the heat from drawing the surfaces.

Example 1 — Outboard-Motor Drive



Design a pair of gears for an outboard-motor drive with the following specifications: 13/25 combination, Zerol bevel gears, 8.5 DP, 0.500-in. face width, 20-deg pressure angle, 90-deg shaft angle, pinion overhung-mounted, gear straddle-mounted. Material for both members is case-hardened steel. These gears are to transmit 15 hp at 4000 rpm of the pinion. Calculate contact stress and working stress.

Procedure: First, determine pinion pitch diameter: $d = N_P/P_d = 13/8.5 = 1.53$ in. Next, determine the transmitted tangential load, using Equation 9:

$$W_t = \frac{126,000(15)}{1.53(4000)} = 309 \text{ lb}$$

Pitch-line velocity, from Equation 10, is $v = 0.262(4000)(1.53) = 1600$ fpm.

Other items to be determined are: Geometry factor $I =$

0.065 from Fig. 3. Face width $F = 0.500$ in. Overload factor $C_o = 1.25$ from Table 2, assuming light shock load on the drive. Dynamic factor $C_v = 1.00$ for top-quality Zerol gears, Fig. 1. Size factor $C_s = 1.00$. Load-distribution factor $C_m = 1.1$ for one member straddle mounted, Table 3. Surface-condition factor $C_f = 1.0$. Elastic coefficient $C_p = 2800$ for steel on steel, Table 1.

The calculated contact stress can now be determined with Equation 1:

$$s_c = 2800 \sqrt{\frac{309(1.25)}{1.0} \left[\frac{1}{0.5(1.53)} \right] \left[\frac{1.0(1.1)(1.0)}{0.065} \right]} \\ = 259,000 \text{ psi}$$

Factors needed for the working stress are: Allowable contact stress $s_{ac} = 250,000$ psi for high-hardness carburized gears, Table 4. Life factor $C_L = 1.0$ for a life in excess of 10,000,000 cycles, Fig. 5. Hardness ratio factor $C_H = 1.0$ for materials of equal hardness. Temperature factor $C_T = 1.0$ assuming an operating temperature not in excess of 200 F. Factor of safety $C_B = 0.86$, Table 5, assuming a certain degree of risk is acceptable in this application.

Working stress can now be determined with Equation 2:

$$s_w = \frac{250,000(1.0)(1.0)}{1.0(0.86)} = 290,000 \text{ psi}$$

In this case the calculated contact stress is less than the working stress so that these gears should be acceptable for this drive. Of course, the gears should also be checked for strength before a final conclusion is drawn.

Example 2 Stock Gears



Design a pair of stock gears with the following specifications: 24/36 combination, spiral bevel gears, 4 DP, 1.500-in. face width, 20-deg pressure angle, 35-deg spiral angle, 90-deg shaft angle, both members overhung mounted. Material for gear is heat-treated steel with a hardness of 300 Bhn. Material for pinion is case-hardened steel with a hardness of 58 Rc. Find the power rating for the gears based on surface durability. Assume that the rating is to be based on a pinion speed of 2000 rpm.

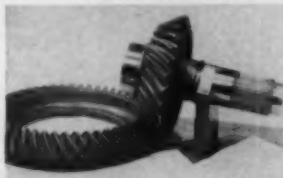
Procedure: Since in this case two materials are specified, it is the material with the lower hardness that sets the allowable stress. Therefore, allowable stress $s_{ac} = 135,000$ psi, Table 4. Pinion pitch diameter $d = N_P/P_d = 24/4 = 6.0$ in. Hardness-ratio factor $C_H = 1.0$ for

gear ratio below 8 to 1. Life factor $C_L = 1.0$ at endurance limit, Fig. 5. Elastic constant $C_p = 2800$ for steel on steel, Table 1. Temperature factor $C_T = 1.0$, assuming a reasonable operating temperature below 200 F. Factor of safety $C_s = 1.0$, Table 5, assuming normal risk. Pinion speed $n_P = 2000$ rpm, assumed for rating purposes. Face width $F = 1.500$ in. Geometry factor $I = 0.091$ from Fig. 4. Pitch-line velocity $v = 0.262 (2000)(6.0) = 3150$ fpm from Equation 10. Velocity factor $C_v = 0.76$ from curve 2, Fig. 1, for commercial-quality spiral bevel gears. Overload factor $C_o = 1.0$ assuming uniform loading for rating purposes. Load-distribution factor $C_m = 1.25$ since both members are assumed to be overhung-mounted, Table 3. Size factor $C_s = 1.0$. Surface-condition factor $C_f = 1.0$.

Equation 4 gives the allowable power:

$$P_{ac} = \left[\frac{135,000(6.0)(1.0)(1.0)}{2800(1.0)(1.0)} \right]^2 \left[\frac{2000(1.5)}{126,000} \right] \times \left[\frac{0.091(0.76)}{1.0(1.25)(1.0)} \right] = 111 \text{ hp at 2000 rpm of the pinion}$$

Example 3 Helicopter Drive



Design a helicopter transmission to meet the following specifications: Right-angle spiral bevel drive with 3000-rpm input speed and approximately 1450-rpm output speed. Maximum power for take-off is 2100 hp, not to exceed 5 per cent of the total life. Cruising power is 1500 hp. It is assumed that these gears will be case-hardened steel with ground tooth surfaces. A 35-deg spiral angle is specified in order to achieve quiet operation. Life requirement is 5000 hr. Find the required gear size to satisfy these conditions with respect to surface durability.

Procedure: Based on the foregoing requirements, life of the gears at maximum load will be 250 hours. At a speed of 3000 rpm the total number of pinion cycles will be 45,000,000. Therefore, these gears must be designed for the maximum horsepower, for continuous duty.

Pertinent factors are: Power $P = 2100$ hp. Overload factor $C_o = 1.0$, assuming that there will be no overloads in excess of the maximum power stated. Pinion speed $n_P = 3000$ rpm. Dynamic factor $C_v = 1.0$ for top-quality gears. Load-distribution factor $C_m = 1.1$, assuming that one member will be straddle mounted, that the gear box will be tested for deflections, and that corrections in gears and mountings will be made if required. Size factor $C_s = 1.0$. Surface-condition factor $C_f = 1.0$. The desired gear ratio is $m_G = 3000/1450 =$

2.07. Therefore, the following tooth combinations may be considered: $N_P/N_G = 15/31, 16/33, 24/50, 25/52, 26/54, 27/56, 28/58$. For quietness the larger tooth numbers are preferable. Also, it is desirable to avoid common factors. Therefore, select $N_P = 25, N_G = 52$.

Additionally, geometry factor $I = 0.117$, Fig. 4. Elastic constant $C_p = 2800$ for steel on steel, Table 1. Temperature factor $C_T = 1.0$, assuming an operating temperature of 160 F. Factor of safety $C_s = 1.1$ for high reliability, Table 5. Allowable contact stress $s_{ac} = 250,000$ psi for case-hardened steel with 60 Rc minimum hardness, Table 4. Hardness-ratio factor $C_H = 1.0$ for materials of equal hardness. Life factor $C_L = 1.0$ for maximum life.

Gear size may be determined with Equation 5:

$$d^3 P = \left[\frac{126,000(2100)(1.0)}{3000(1.0)} \right] \left[\frac{1.1(1.0)(1.0)}{0.117} \right] \times \left[\frac{2800(1.0)(1.1)}{250,000(1.0)(1.0)} \right]^2 = 125$$

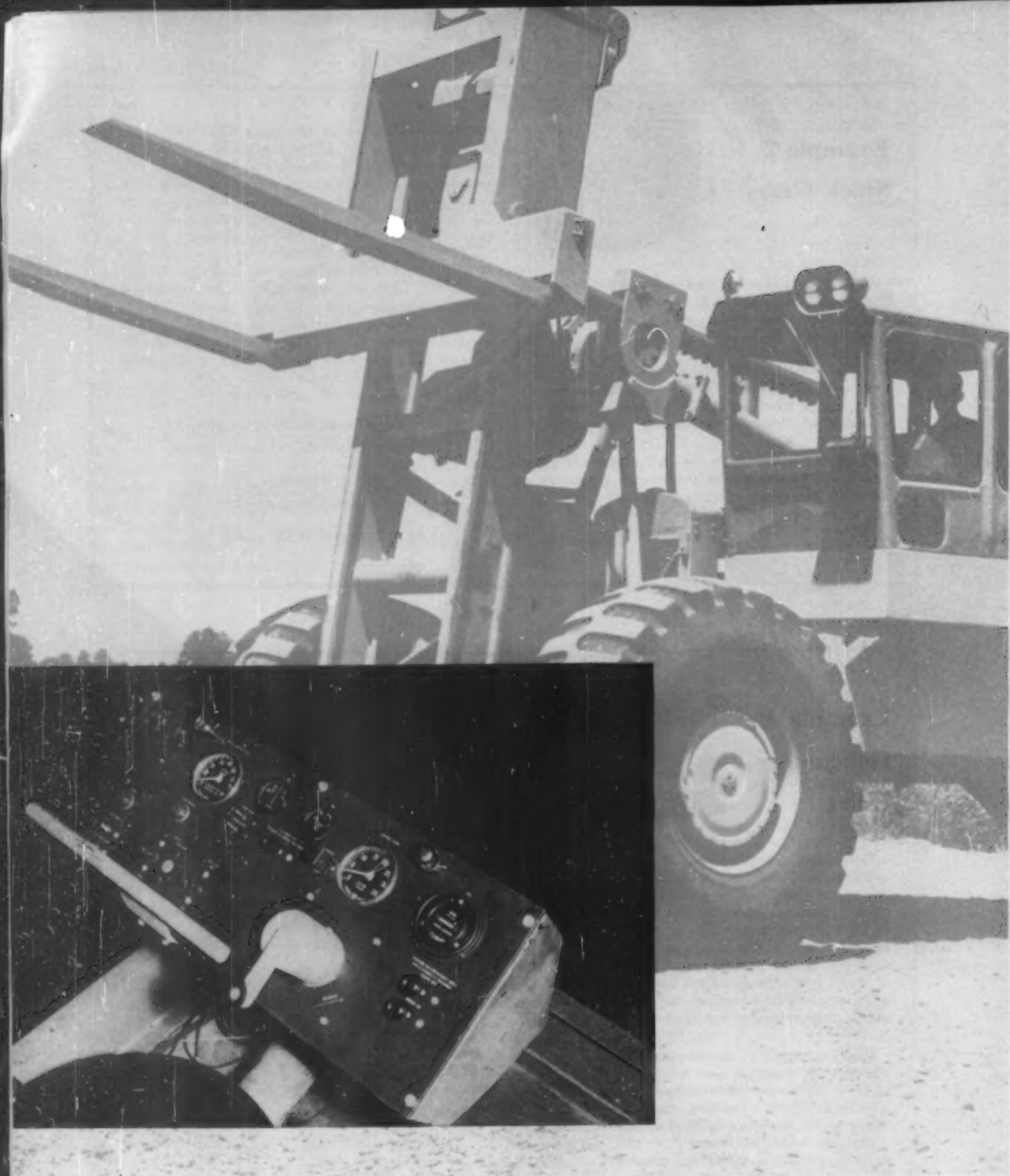
and from Equation 7,

$$d^3 = \frac{125}{0.15 \sqrt{1 + (207)^2}} = 362$$

$$d = 7.14 \text{ in.}$$

Therefore, diametral pitch $P_d = N_P/d = 25/7.14 = 3.5$ and face width $F = 125/(7.14)^2 = 2.41$ in.

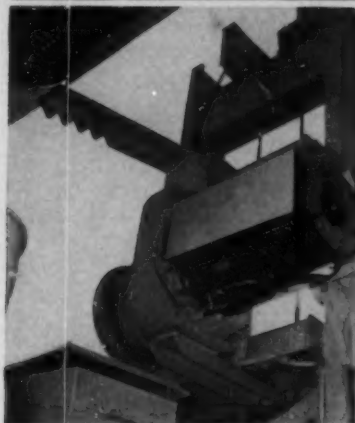
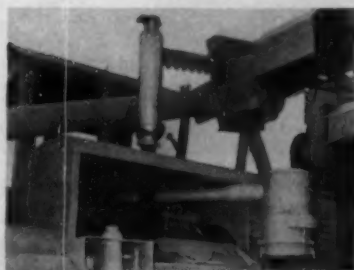
For an aircraft application such as this, it is essential that the gears be checked for strength as well as surface durability.

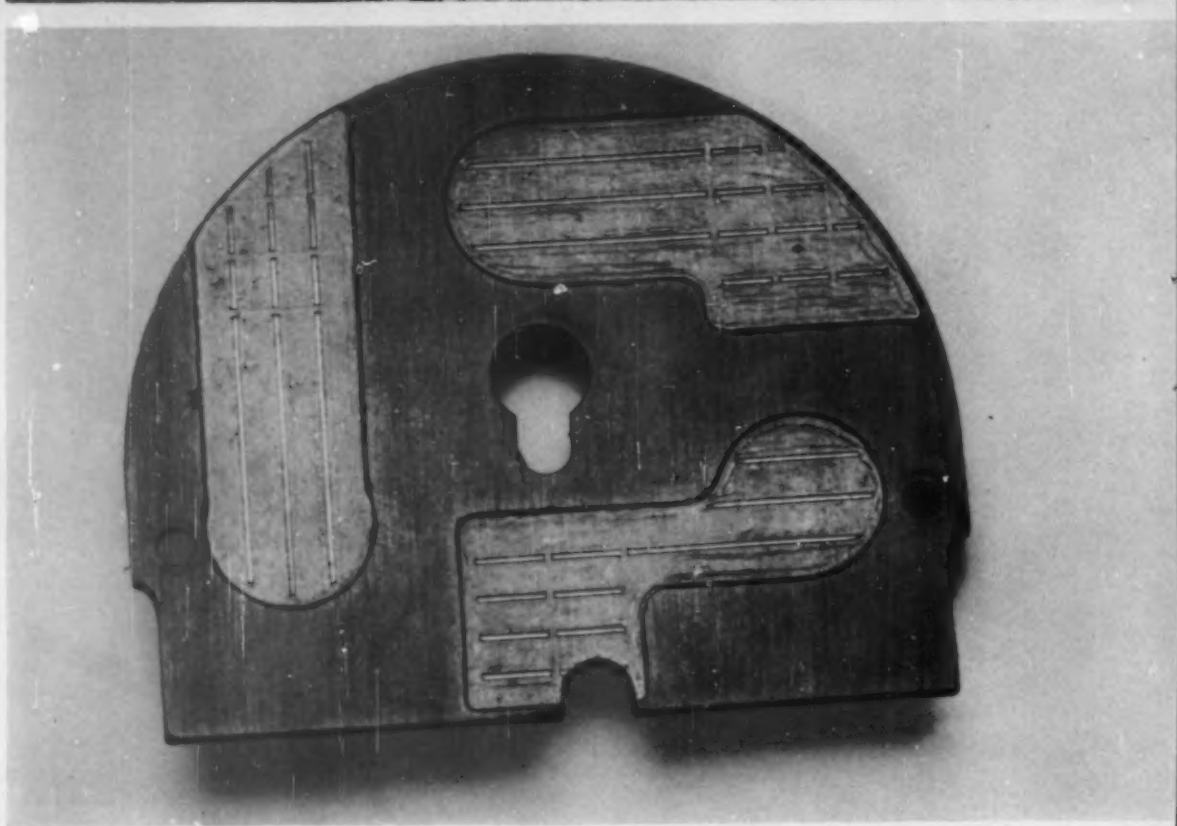
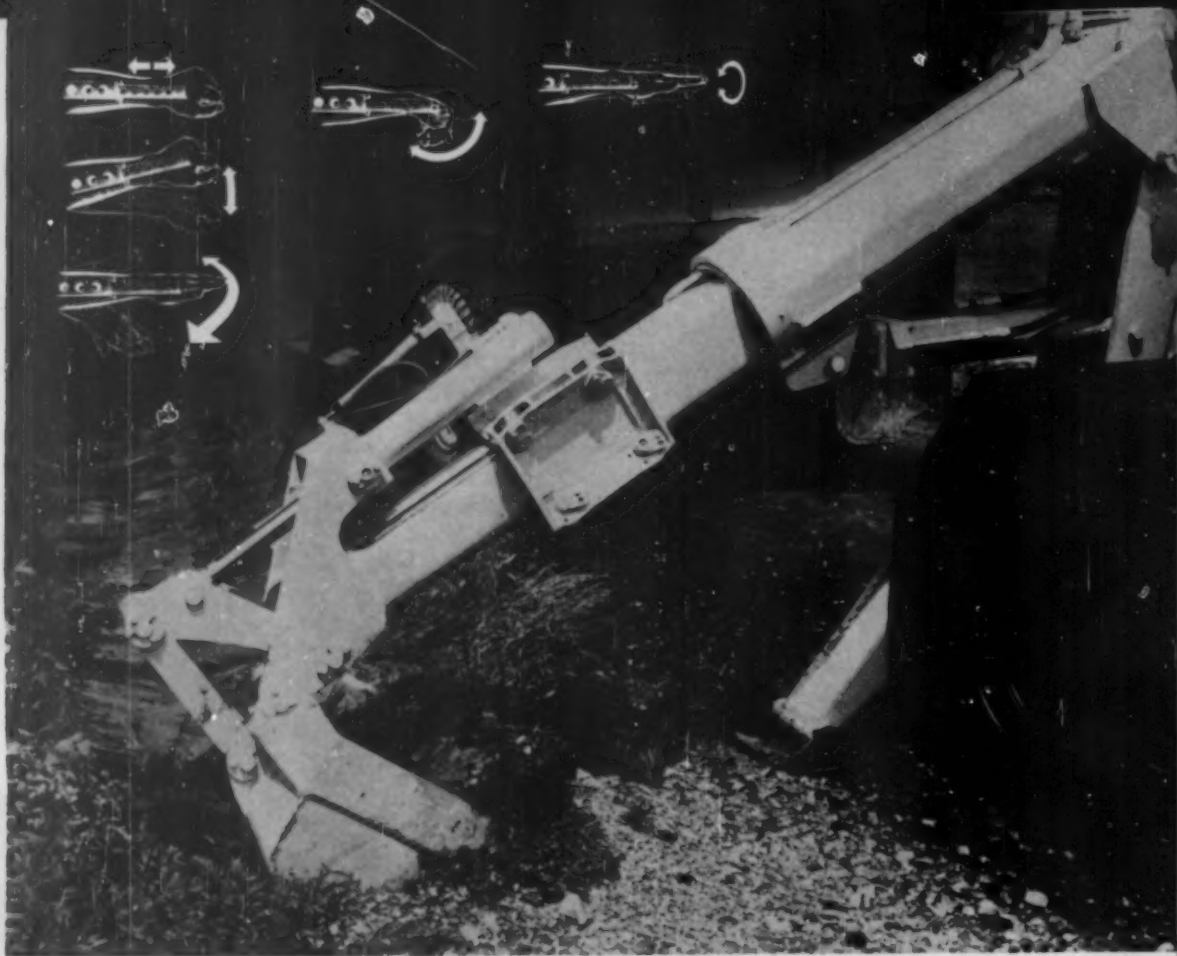


Diesel-Electric Lift Truck

Flip switches at his fingertips permit the operator of an out-sized fork-lift truck to maneuver 20-ton loads as easily as he handles a 2-ton pallet. When he turns on his revolving stool to watch operations through the back window, the control panel, mounted to the stool post, moves with him. A diesel-electric powerplant supplies power for all machine functions—dc for the LeTourneau Electric Wheels that propel the vehicle; ac for the quick-responding maneuvering motors. Steering motor, below, drives a spur gear that walks around a fixed segment to turn the rear wheel. The unit was designed by R. G. LeTourneau Inc., Longview, Tex.

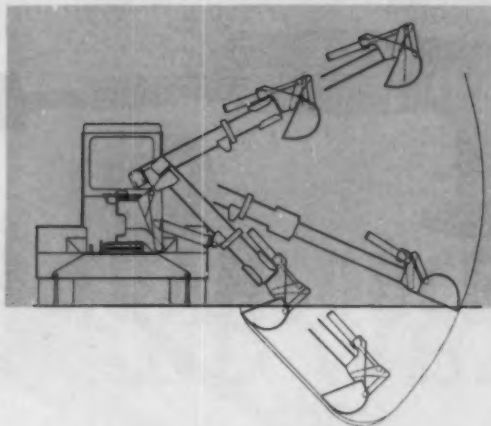
A-C motor operates a rack-and-pinion mechanism to tilt the fork mast (top). Winch raises and lowers fork on the mast by means of a cable-pulley system (center). Spur gear walks around fixed quadrant to steer the vehicle (bottom).





Ditch Cleaner

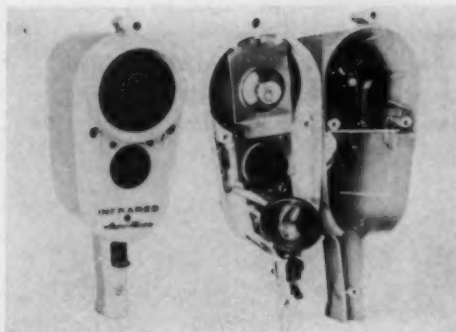
A hydraulic telescoping boom changes a back hoe into a highway ditching machine. Hydraulic cylinders produce five manipulator-like motions: Telescoping boom, Raising and lowering boom, Horizontal boom swing, Wrist hoeing action, and Rotation. Down pressure can be controlled. Interchange of booms is simple. It involves withdrawal of two pins and quick disconnect of six hoses. Called Gradall Hydro-Scopic, the boom is built at Warner and Swasey's Badger Division, Winona, Wisconsin. It's supplied with the company's Hopto 200.

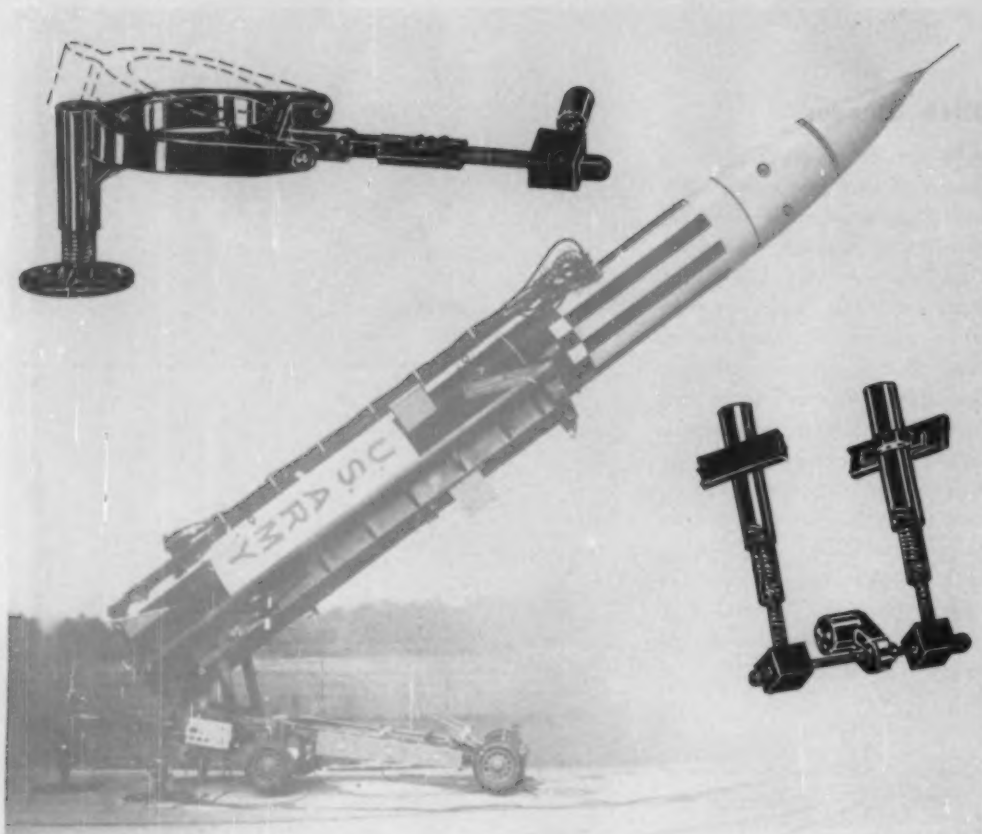


design in action

Black-Light Phone

Die-stamped circuit—claimed to be more rugged than a printed circuit — forms electrical connections in an infrared light phone. Although the dies are more expensive than the equipment needed to fabricate printed circuits, volume production earns back their cost because production time is greatly reduced. Bosses on the copper conductors, which act as stops for contactor strips, could not have been produced on conventional printed circuits. The toy phone, known as Astro-Phone, changes the spoken word to modulated infrared light waves in the transmitting unit, and back again into distinguishable sounds in the receiver. The microphone vibrates a mirror to modulate the light. Infrared filters remove background "noise" for better reception. Die-stamped circuits are produced by Dytonics, Inc., Rochester, Mich.





Pershing Transporter-Erector

Unbalanced pair of motors lifts the Pershing missile to firing position. The larger 11-hp motor works with the smaller to extend the elevating jacks at 0.9 ips to gross position. The smaller $\frac{3}{4}$ -hp motor works alone to make fine adjustments in position. It extends the same jacks at 0.02 ips. The two motors drive the jacks through a centrally located gearbox. Jacks are double extending ball screws. A similar motor-driven ball screw swings the launch pad into position in 15 seconds. Three adjustable feet level the launch pad on any terrain. The transporter-erector, developed by Thompson Ramo Wooldridge's Tapco division, can be delivered by airplane, helicopter, or tracked vehicle. Ball-screw assemblies were furnished by Saginaw Steering Gear Div., General Motors Corp., Saginaw, Mich.

TRANSDUCERS AND WHAT they MEASURE

basic electronic controls

1

JACOB H. RUITER, JR.

Weston Instruments Div.
Daystrom Inc.
Newark, N. J.

and

R. GORDON MURPHY

Wallace & Tiernan Inc.
Belleville, N. J.

Heat, force, light, pressure—these and many other physical properties can be measured. Often, knowledge of their magnitudes, their variations, or even whether they are present, is required for making decisions or controlling processes.

Sensing devices, or transducers, have been developed to convert almost every physical property into a measurable signal. Because electrical quantities can be easily measured, amplified, transmitted, and controlled, transducers which provide electrical outputs are the most common, and are the only types considered here.

Also covered are the most frequently encountered physical properties. For measuring each property, specific transducers are recommended, and typical circuits or control arrangements are described.

This article is the first of two on electronic controls. The second article will discuss indicators, recorders, and control devices. Both articles are based on chapters from a new book, *Basic Industrial Electronic Controls*, to be published in January, 1962, by Holt, Rinehart, & Winston Inc.

TRANSDUCERS

Any device which converts one form of energy into another is called a transducer. For example, a thermocouple transforms heat energy into electrical energy; a microphone converts sound into electrical energy; a strain gage converts stress into electrical energy; and an accelerometer converts acceleration into electrical energy.

The term "transducer" may also be applied in the reverse direction. For example, a loudspeaker converts electrical energy into sound, and a solenoid converts electrical energy into mechanical motion. Usually, however, the term "transducer" applies to the device which senses a physical quantity and converts it into an electrical value for measurement. Devices which convert electrical energy into another form of energy, such as a solenoid, are referred to as actuators because their immediate result is a positive physical action.

RESISTIVE TRANSDUCERS

Resistive transducers are units in which the ohmic resistance of an electrical element is changed to produce a variation in an electrical circuit. The variation can then be measured and related to the initial means which produced the change. Measurement is generally made by inserting the transducer as one branch of a bridge circuit or simply by measuring the difference in current flow in the circuit with an ammeter.

Resistive transducers generally fall into two groups: 1. Those whose resistance is varied by a physical or chemical change. 2. Those whose resistance is varied by the movement of contacts.

Physical or Chemical Change: A typical transducer which uses a change in dimensions to affect resistance is a wire strain gage, Fig. 1. A fine-wire filament about 0.001 in. in diameter is formed into a grid pattern and attached securely to, but insulated from, the item on which the strain is to be measured. As strain is applied to the item, strain is also applied to the fine-wire filament. The wire in a strain gage is usually an alloy of copper and nickel which has a relatively high elasticity. As strain stretches the wire, the cross section is reduced and the overall length is increased. Both these factors cause an increase in electrical resistance. The change in resistance of the strain gage is measured and calibrated in terms of strain.

Other examples of transducers which use a change in physical or chemical characteristics are: A strip of cotton fiber, impregnated with saline solution, which changes resistance with humidity; metallic springs which change resistance with elongation; carbon discs or granules which change resistance with pressure; wire which changes resistance with

pressure, voltage, current, or temperature. Any material whose internal resistance varies when exposed to some physical phenomenon can be used to produce a signal for observation of that phenomenon.

RESISTIVE TRANSDUCERS

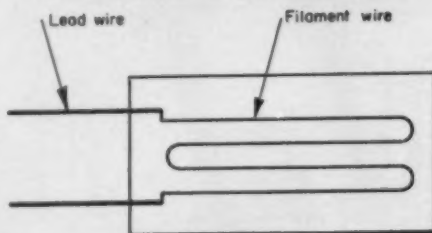


Fig. 1—Wire strain gage in which a physical change affects electrical resistance. Lead wires are securely fastened to the test item so they produce no strain on the fine-wire filament during the test procedure.

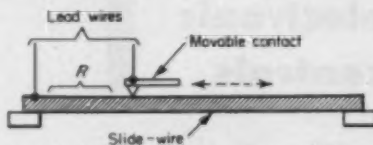


Fig. 2—Slide-wire resistive transducer. Resistance changes when a contact is moved along the length of the resistive element.

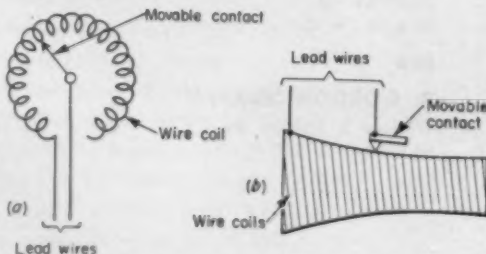


Fig. 3—Resistive transducers for either uniform, a, or nonuniform, b, resistance changes.

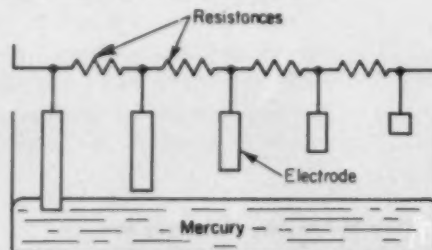


Fig. 4—Liquid-type resistive transducer in which a rising mercury level shorts out successive resistances of predetermined values.

Movable Contacts: Resistance elements which have movable contacts are made in many different mechanical forms to suit different applications. The best known unit is probably the slide-wire rheostat or potentiometer. In Fig. 2, as the contact moves to the right, resistance R increases; as the contact moves to the left, resistance R decreases. This, a straight length of wire, is the simplest form of potentiometer.

Two other forms are an assembly of coiled or folded wire and a tapped resistance coil. The configuration of the coil may be straight, to sense a reciprocating motion, or wrapped around a circular form, to sense angular displacement, Fig. 3a. If the cross section of the form and the wire diameter are constant, the change in resistance will be linear and directly proportional to the movement of the contact. In cases where a nonlinear output is desired, the coil may be wound on a form having a nonuniform cross section, Fig. 3b.

The slide-wire rheostat, although well known, is not the only resistance-type transducer available. Other resistive transducers vary resistance by changing the cross-sectional area of the resistance element or by adding or subtracting conducting paths in parallel.

In addition to metallic wire units, resistance-type transducers can be made from carbonaceous materials, mercury, or electrolytes. A mercury unit is shown in Fig. 4. As the level of mercury rises in the container and contacts the electrodes or probes, resistance elements are removed by short-circuiting them through the mercury.

Electrical resistance (or conductivity) of solutions is used to determine pH (acidity or alkalinity), oxidation-reduction potential (Redox), and electrolytic conductivity. These electrochemical measurements are made by inserting special electrodes of a variety of materials into a solution and passing a current through the solution. The voltage drop across the solution is a measure of the solution conductivity and can be calibrated in terms of the characteristic being measured.

CAPACITIVE TRANSDUCERS

A capacitive transducer is a variable capacitor whose capacitance is varied by some physical condition such as chemical composition, level, pressure, thickness, or vibration. It consists of two conducting plates and a dielectric. The capacitance of any capacitor is changed by varying: 1. Distance between the plates, that is, by increasing or decreasing the thickness of the dielectric. 2. Area of the plates. 3. Strength of the dielectric. The electrodes must be accurately spaced originally, and the capacitance in the leads as well as in the input to the measuring instrument must be kept low.

A simple type of capacitive transducer for measuring pressure in a fluid line is screwed into a fitting in the line, Fig. 5. The transducer consists of two capacitor plates (A and B), the insulator, adjusting bushing, housing, and lead wires. Plate A is stationary and is mounted in the insulator. The adjusting bushing holds plate A firmly in position and permits it to be adjusted at a predetermined position with respect to plate B . Plate B , a thin, pressure-sensitive diaphragm, is electrically connected to the housing. The lead wires are connected to plate A through the center conductor and to plate B through the housing. As line pressure increases, the diaphragm moves closer to plate A , and the capacitance increases. Conversely, as line pressure decreases, the distance between plates A and B increases, and the capacitance decreases.

A similar type of transducer is used for measuring density, flow, thickness, and length. For such measurements, both plates of the capacitor are held fixed. The material being measured serves as the dielectric so that variations in material thickness or density produce variations in the dielectric constant of the capacitor.

MAGNETIC TRANSDUCERS

Units which operate on magnetic principles are useful for indicating all forms of motion. Motion

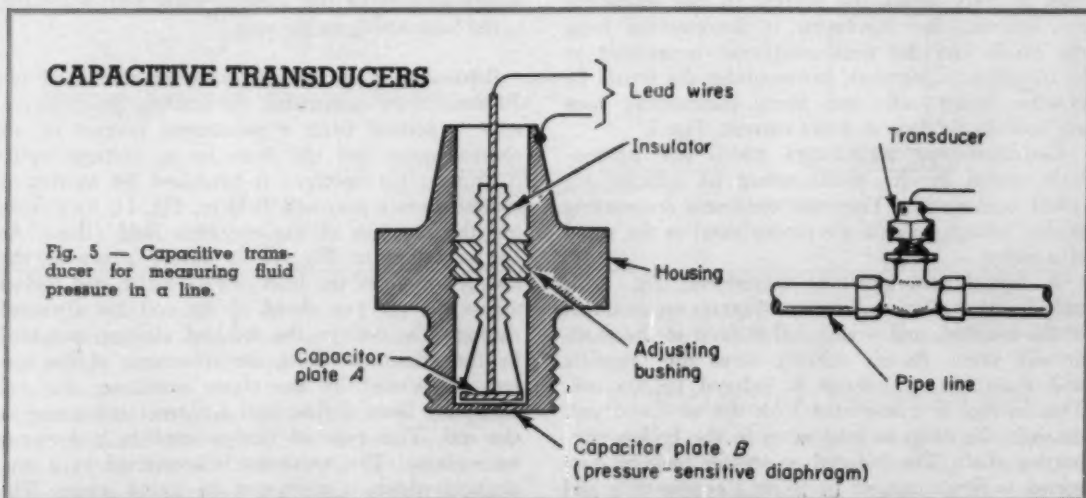


Fig. 5 — Capacitive transducer for measuring fluid pressure in a line.

may be used to vary the position or strength of a magnetic field or change the position of a coil. Usually, magnetic transducers operate without physical contact with the mechanism from which measurements are being obtained. This feature results in negligible or small loading effects on the mechanism being measured. Yet, magnetic transducers produce sizeable voltages. Elements based on magnetic principles can be divided into three types: 1. Generator. 2. Inductance. 3. Reluctance.

Generator Type: This type of magnetic transducer is a voltage generator. It operates on the principle that a voltage is induced in a conductor which cuts magnetic lines of force. If a conductor is stationary or moved parallel to the lines of force, no voltage is generated.

Because it is not mechanically feasible to move just one wire so it cuts lines of force, a loop is formed and rotated in the magnetic field. This loop, or coil, thus becomes two conductors in series. In the coil positions of Fig. 6a and c, no voltage is induced in the conductors. As the coils rotate, they cut more and more lines of force. Maximum voltage is developed when the conductors are at the centers of opposite poles where they cut lines of force at right angles.

Because of the direction of coil rotation and the direction of the lines of force, the current induced in a conductor (or coil) reverses its direction each time that conductor comes under the influence of a pole of opposite polarity. When slip rings are attached to each end of the coil, Fig. 6a, this basic alternating current can be collected and supplied to a load.

A split ring, or commutator, Fig. 6c, can also be used to supply fluctuating direct current. Because current in any conductor that moves in a given direction past a given pole always flows in the same direction, a collector brush need only be connected successively to each conductor that passes through a specific arc. Thus, the current supplied to a brush varies from zero to a maximum and back to zero. Before the current in one conductor can reverse, that conductor is disconnected from the brush and the next conductor, terminated at its commutator segment, moves under the brush. In practice, many coils and many commutator bars are used to produce a direct current, Fig. 7.

Generator-type transducers which are particularly useful in the measurement of velocity are called tachometers. They are connected to rotating shafts; voltage outputs are proportional to the speed of rotation.

A typical generator-type transducer, Fig. 8, is used for measuring air velocity. Magnets are mounted in the housing, and a wire coil is fixed to the shaft, or vice versa. As air velocity turns the propeller and shaft, an ac voltage is induced in the coil. This voltage is transmitted from the air-speed unit through slip rings to lead wires in the hollow supporting shaft. The induced ac voltage may be converted to direct current by using a commutator and

brushes, or it may be rectified. The dc voltage is then transmitted to an indicator or a recorder. The directional vane positions the unit with the propeller facing into the maximum air velocity.

Dc voltage tachometers are useful from 150 to 5000 rpm, but above this speed a voltage ripple appears in the output. Ac units are either voltage or frequency responsive. In a voltage-responsive unit the ac voltage output is rectified and indicated on a dc voltmeter. With a frequency-responsive unit, the number of revolutions per minute is indicated on a frequency meter.

Inductance Type: Inductance or variable-inductance units consist of two parts—a coil of wire and a movable magnetic core. Alternating current is passed through the coil, and the movable core is connected to an actuating force. As the core moves linearly within the coil, the inductance of the coil varies. Since the current passing through the coil is inversely proportional to the inductance, a meter measuring the current can be calibrated in terms of the position of the core.

A modified unit, Fig. 9, is used to increase the sensitivity of the response. A center tap is taken from the coil, and the movable core is fully inserted in the coil. The center tap essentially provides two coils around the core. As the core is moved, the inductance is increased in one coil and decreased in the other. Thus, the difference in inductance between the two coils provides twice the sensitivity of a single-coil unit.

A third type of inductance unit is the differential transformer or a mutual-inductance unit, Fig. 10. It consists of three coils wound on a common form with a movable core of magnetic material. The center or primary coil is connected to an ac source which, through magnetic flux in the armature, induces voltage in the two outside or secondary coils. If the movable core is centrally located, voltages induced in the two secondary coils are equal. When the core is displaced from center by an actuating force, induced voltage is increased in one secondary coil and decreased in the other. This difference in voltage can be measured, related to the position of the movable core, and calibrated to the force acting on the core.

Reluctance Type: These units are similar to inductance units except that the exciting electrical energy is derived from a permanent magnet or an electromagnet and not from an ac voltage input. A current (or voltage) is produced by moving a conductor in a magnetic field or, Fig. 11, by changing the strength of the magnetic field (flux). As the armature in Fig. 11 is moved closer to the magnet, more of the lines of flux which had leaked across the air gap ahead of the coil are attracted through the coil to the reduced air gap provided by the armature. Thus, the reluctance of the system is reduced by the closer armature, the coil cuts more lines of flux, and a current is induced in the coil. This type of unit is used in a dynamic microphone. The armature is connected to a diaphragm which is positioned by sound waves. The

MAGNETIC TRANSDUCERS

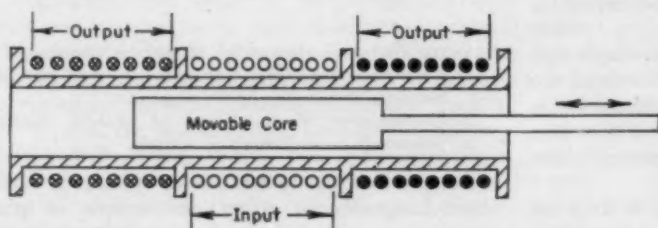
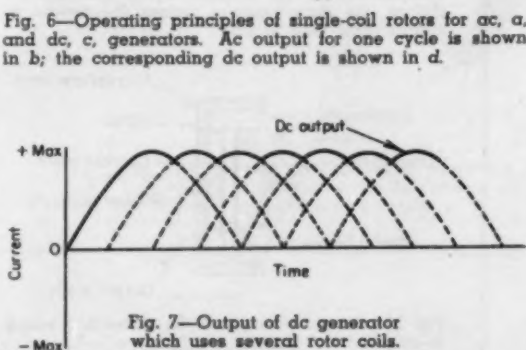
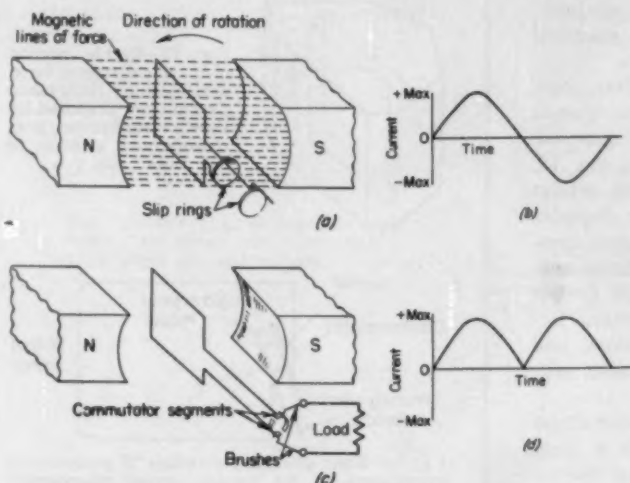
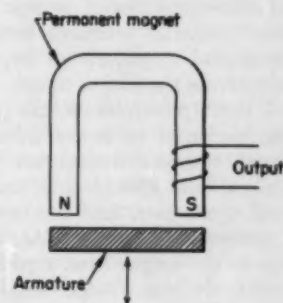
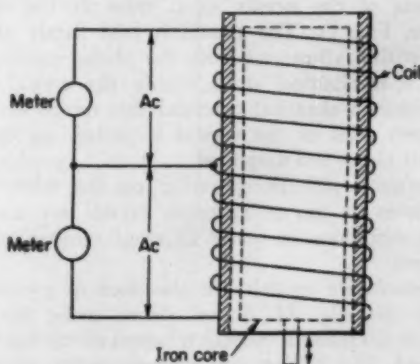
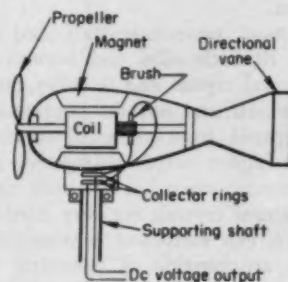


Fig. 11—Reluctance transducer which uses a moving armature to vary the lines of flux passing through a coil.



reverse procedure is used in a permanent-magnet loudspeaker.

A reluctance-type unit may also be used as a magnetic thickness gage. The thickness of the plate being measured determines the reluctance of the magnetic path and the flux density. An increase in plate thickness increases the flux, which in turn

increases the current output of the coil.

PIEZOELECTRIC TRANSDUCERS

Piezoelectricity is a property exhibited by crystals of certain materials. These crystals, when subjected to mechanical stress, show a difference in

electrical potential at certain points of their structure. Piezoelectric transducers make use of this property by arranging some means of applying mechanical stress to the crystal and reading the electrical variation.

The most common crystals used are quartz, tourmaline, Rochelle salts, and barium titanate. Quartz is a natural crystal and is either mined or quarried. Rochelle salt and barium titanate crystals, Fig. 12, are prepared from chemical solutions and exhibit a much higher output voltage for a given displacement, stress, strain, or pressure than quartz crystals. Natural crystals are very hard and strong and, therefore, can withstand considerable shock. Quartz crystals are capable of operating at constant frequencies with very slight frequency variations, and they can withstand higher temperatures than artificial crystals.

The most familiar type of piezoelectric transducer is the phonograph pickup. It is used in a large percentage of home record players to sense the vibrations of the needle as it rides in the record groove, Fig. 13. The crystal is held firmly at one end so that vibrations from the phono needle produce a mechanical stress within the crystal. The difference in electrical potential that results between the two sides of the crystal is picked up by the contact plates and amplified.

Vibration pickups operating on the same basic principles as the phonograph crystal are used to sense vibrations in many different mechanical operations.

Piezoelectric crystals are also used in crystal microphones, Fig. 14. Sound waves strike the thin conical diaphragm which is attached to the driving rod. The driving rod is mechanically connected to opposite corners of the crystal. The crystal is held firmly at the other two corners by rubber supports. Sound pressure against the diaphragm exerts a force on the two unsupported ends of the crystal through a metal bridge. The difference in electrical potential produced between the two sides of the crystal is picked up by two contact plates and constitutes the output signal.

The basic principles of the crystal microphone can be packaged in many different configurations to supply pressure transducers for a wide variety of applications. Piezoelectric transducers are light in weight, compact, and inexpensive. They provide good performance over a wide range of frequencies.

Because the output from a piezoelectric transducer is a relatively low voltage, amplifiers and accessory circuits are required before the signal can be applied. Errors which may be introduced in the system by additional circuitry and connecting cables can be reduced by placing the amplifier as close to the pickup as possible.

PHOTOELECTRIC TRANSDUCERS

The three conditions which may exist in photoelectric types of transducers are:

1. Photovoltaic effect—generation of an emf between

PIEZOELECTRIC TRANSDUCERS

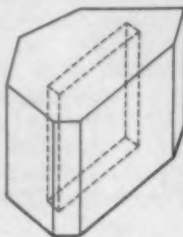


Fig. 12—Usable portion of a typical crystal for a piezoelectric transducer. Crystals are prepared by slow crystallization from a saturated solution of the basic salt.



Fig. 13—Basic operating principle of piezoelectric transducers. In the familiar crystal phonograph pickup, the record groove causes the needle to vibrate from side to side.

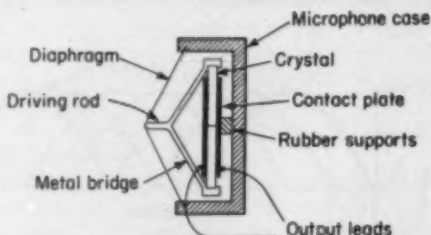


Fig. 14—Crystal microphone for converting sound to an electrical output.

- two electrodes when either of them is illuminated.
2. Photoconductive effect—reduction in the electrical resistance of materials by illumination.
3. Photoemissive effect—emission of charged particles (electrons) from illuminated surfaces.

"Photocell" is a generic term which is applied interchangeably to either photovoltaic or photoconductive units. "Phototube" applies only to photoemissive vacuum-tube devices.

Photovoltaic Type: A wet cell consists of two metal electrodes immersed in a liquid electrolyte. When either of the electrodes is illuminated, an emf is generated between the two electrodes. These units are difficult to handle because of the liquid electrolyte and have been largely replaced by dry cells (barrier-layer type).

One dry type is a selenium cell, Fig. 15. As light strikes the crystalline selenium, a potential which can be measured and recorded is set up between the iron and selenium. Such units are used for light measurements, color matching, and turbidity measurements. When this type is used as a photographic light meter, the generated emf is indicated on a meter in foot-candles of illumination falling

PHOTOELECTRIC TRANSDUCERS

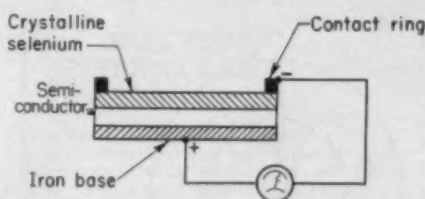


Fig. 15—Dry-type photovoltaic cell which generates an electromotive force when exposed to light.

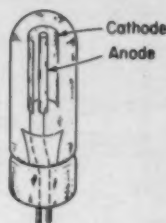


Fig. 16—The two functional elements of a photoemissive transducer, the phototube.

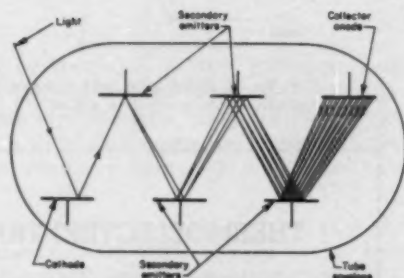


Fig. 17—Elements of a multiplier phototube. Each electron that strikes a secondary emitter causes two electrons to be released by secondary emission.

on the object to be photographed.

Photoconductive Type: A photoconductive unit must be connected to an external source of current. This current is varied by an increase or decrease in the resistance of the cell when the unit is exposed to variations in light intensity. Materials used in this type of cell are selenium, germanium, thallous sulfide, lead sulfide, silicon, and cadmium sulfide. These materials respond to light in the visible spectrum as well as to other wavelengths such as infrared and ultraviolet.

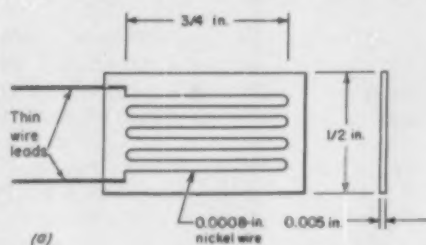
Photoconductive cells that are sensitive to visible light are used in "sun" switches to control circuits for night operation of such items as street lights and navigation beacons, and in pyrometers for low-temperature heat-radiation measurements. Photoconductive transducers are usually used in relay circuits for on-off switching or in bridge circuits when proportional measurements are desired.

Photoemissive Type: Simple phototubes consist only of a photoemissive cathode and an anode, Fig. 16. The cathode is coated with a light-sensitive material (usually a metallic oxide) that emits electrons when it is illuminated. If the anode is made positive with respect to the cathode, electrons emitted by the cathode will be attracted to the anode, and a small current will flow.

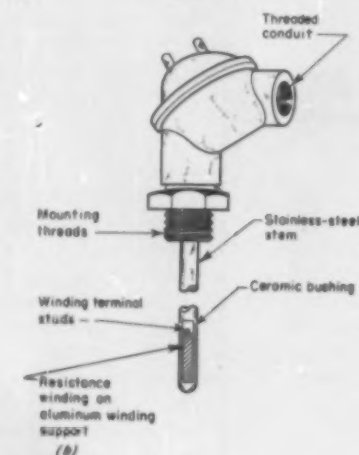
Phototubes may be filled with inert gas at less than atmospheric pressure, or they may be highly evacuated. Current flow in evacuated tubes is very small and must be amplified for almost every application. Gas-filled phototubes develop higher currents because the electrons attracted to the anode strike molecules of gas and ionize them. The free electrons resulting from ionization are also attracted to the anode, increasing the flow of electrons in the tube.

Phototubes can be made with more than one cathode to increase their sensitivity. The principle of secondary electron emission to increase electron flow within the tube is shown in Fig. 17. Light strikes the cathode and emits electrons. Each electron emitted is attracted to the first secondary emitter, or dynode. For each electron striking a secondary emitter, two electrons are emitted. The process continues until all electrons are collected at the anode. With four secondary emitters, each electron initially liberated produces 16 electrons that are collected at the anode—thus, the name multiplier phototube.

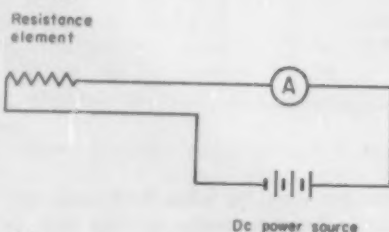
Such amplification generally yields enough signal to operate control devices without additional external amplification. Multiplier tubes are, however, more subject to temperature variations than a simple phototube. They are widely used for measuring scintillations due to radioactivity.



(a)



(b)



(c)

Fig. 18—Flat, a, and round, b, resistance elements for thermoelectric transducers. The ammeter in c can be calibrated to indicate temperature.

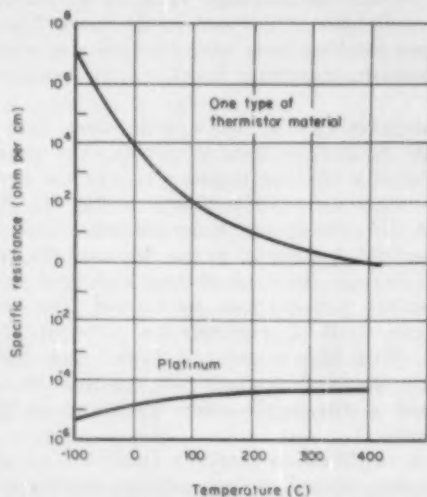


Fig. 19—Temperature-resistance curve for comparing a typical thermistor material with platinum. (Courtesy, Victory Engineering Corp.)

THERMOELECTRIC TRANSDUCERS

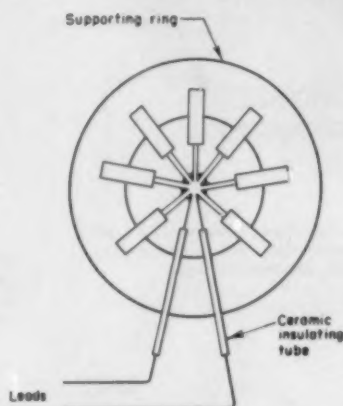


Fig. 20—A thermopile with several thermocouples connected in series.

THERMOELECTRIC TRANSDUCERS

Certain elements produce an electric current or cause an electric current to change when exposed to temperature variations. Although temperature changes can be determined indirectly by measuring changes in color or pressure, this discussion is confined to the type of unit which is directly affected.

The primary thermoelectric devices are: 1. Materials which show a change in electrical resistance as temperature changes (resistance thermometer, thermistor). 2. Dissimilar metals (usually in wire form) which, when joined, produce an emf when their junction is heated (thermocouple).

Resistance Thermometers: These devices are constructed of very fine wire of nickel, platinum, or copper. Some of the more important types used in commercial resistor bulbs are:

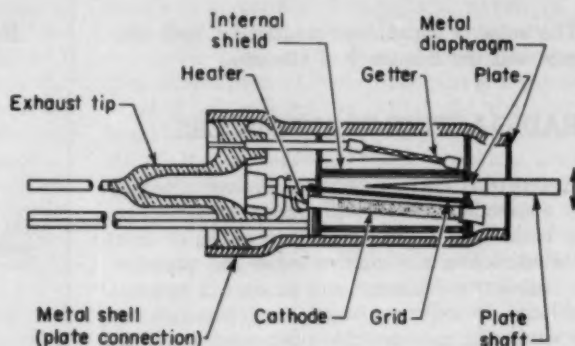
1. Woven wire-mesh cloth for surface temperature measurements.
2. A strip of thin nickel foil.
3. Spaced winding of bare wire over a round insulating arbor.
4. Insulated wire wound in a smooth layer or layers over a ceramic, plastic, or metal arbor, Fig. 18a.
5. Wire wound in a small-diameter coil on an arbor for mounting in a thin-walled insulated metal or ceramic tube or rod, Fig. 18b.

The resistance thermometer makes use of the principle that electrical resistance of most conductors increases as temperature increases. A constant dc voltage is applied to the resistance element, Fig. 18c, and current is measured with an ammeter. If the element is heated, its resistance increases and the current decreases. The ammeter can be calibrated in thermal degrees.

When precise measurements are required or small differences in temperature must be measured, re-

ELECTRONIC TRANSDUCERS

Fig. 21—RCA Type 5734 mechanoelectronic transducer for converting mechanical vibration at the plate shaft into tube-current variations. (Courtesy, Radio Corp. of America.)



sistance units can be connected as the unknown element in bridge circuits. Because resistance elements are made with very fine wire, resistance thermometers respond rapidly to temperature changes. They operate most efficiently from -80 to 150°C (-110 to 300°F).

Thermistors: These units are made of solid semiconducting materials which experience a decrease in electrical resistance with an increase in temperature. Conversely, their electrical resistance increases with a decrease in temperature, Fig. 19.

The materials are any of a number of metal oxides, or a combination, including oxides of cobalt, copper, iron, magnesium, manganese, nickel, tin, titanium, uranium, and zinc. These oxides are formed into many different shapes—discs, washers, rods, beads, or flakes—depending on the material and the application. Electrical contact is made by embedding wires in the material before it is crystallized in a kiln. The wire leads can be ordinary copper wire since the thermistor can be operated with high potential and low current because of its own inherent resistance.

When the thermistor is used in a bridge circuit, an increase in the temperature of the thermistor decreases its resistance and upsets the balance of the bridge. The bridge is then rebalanced and the amount of resistance required is calibrated to the temperature change in the thermistor.

The voltage-current characteristic of a thermistor is linear, providing very little power is dissipated in it. Thus, when the thermistor is connected to a voltage source, the voltage across the thermistor varies with temperature. As a result, temperature is measured with a voltmeter calibrated in temperature. If, however, large amounts of power are dissipated in the thermistor, there will be a temperature rise in the thermistor. Such a situation must be avoided.

Many applications of thermistors as transducers are for other than direct temperature measurements. All, however, use the characteristic of negative temperature coefficient of resistance.

Thermocouples: In these elements, two dissimilar

metals are welded together at one end. When this junction is heated, a voltage is developed across the free ends proportional to the temperature difference between the welded ends and the free ends. Frequently used combinations of two-metal conductors include copper-constantan, iron-constantan, chromel-alumel, and noble metals such as platinum-platinum rhodium. The first two combinations are used for measurements ranging from -300 to 1600°F ; chromel-alumel, from -300 to 2000°F ; and platinum or platinum alloy elements, from 32 to 2800°F . A group of thermocouples connected in series forms a thermopile, Fig. 20.

ELECTRONIC TRANSDUCERS

One type of electronic transducer is the cathode-ray tube, which is most commonly used in an oscilloscope.* The oscilloscope is normally regarded as an indicator, and as an indicator, it is an instrument for quantitative measurement.

In addition, the cathode-ray tube is a transducer because it converts electrical energy to light energy. As a transducer, it detects the presence of both magnetic and electrostatic fields and measures the strength of these fields by measuring the amplitude of the deflection produced on the electron beam in the tube. In the electronics field it is used primarily as a test instrument rather than an indicator for process control.

Another type of electronic transducer is the mechanoelectronic transducer, a special electron tube, Fig. 21. The plate of the tube is a wedge-shaped piece of metal which is attached to a shaft that passes through a thin metal diaphragm to the outside of the tube. The plate shaft is mechanically coupled to the source of vibration. Mechanical vibration of the plate shaft varies the distance between fixed grid and plate. As the plate is moved closer to the grid, more current flows in the tube. Conversely, as the plate is moved away from the grid, less current flows. Thus, the tube converts mechanical vibration into variations in electric cur-

*J. H. Rutter, Jr.—*Modern Oscilloscopes and Their Uses*, Holt, Rinehart, & Winston Inc., New York, 1955.

rent. The tube is capable of translating both the amplitude and the frequency of vibration.

RADIOACTIVE TRANSDUCERS

Radioactivity is that property or process whereby certain materials spontaneously emit particles, or rays, or both, by the disintegration of nuclei of their atoms. Radioactive transducers sense the products of this radioactive discharge and produce a measurable voltage or current. Instruments presently in use to sense and measure this phenomenon are: 1. Geiger-Mueller tubes. 2. Ionization chambers. 3. Scintillation counters.

The three types of nuclear energy that are detected by these units are alpha particles, beta particles, and gamma rays. Alpha particles are protons which are relatively large and, therefore, have little penetrating power. Alpha particles cannot penetrate even a single page of paper. Beta particles are electrons. Therefore, their mass is less than $1/1850$ th of the mass of an alpha particle. Beta particles travel at very high velocities and, since they are so small, can pass through many materials. Gamma rays are similar to x-rays but have an even shorter wavelength. Gamma rays will pass through most materials, including thin sheets of lead.

Geiger-Mueller Tubes: A Geiger-Mueller tube is a small cylindrical metal tube filled with an inert gas, such as argon or krypton, at less than atmospheric pressure, Fig. 22. A fine wire, the anode, extends inside the tube and is insulated from the ends. At one end of the tube is a window of beryllium, mica, Mylar, or other material which is relatively transparent to nuclear energy.

A positive potential of 500 to 3000 v is applied to the wire anode while the metal shell is maintained at ground potential. Under quiescent conditions, no electrical discharge occurs between wire and shell. If a beta particle enters through the window, it strikes the molecules of inert gas, and ionization of one or more molecules takes place. The negatively charged ions (electrons) are attracted to the anode. As these electrons approach the thin wire anode, they are concentrated in a small area, and further ionization of the gas occurs. As ionization increases, a discharge occurs across the tube. The impulses are fed to a suitable amplifier. The rate of these impulses or discharges is a measure of the radioactivity.

Geiger tubes cannot measure alpha particles because alpha particles cannot pass through the window. Gamma rays are unlikely to ionize the molecules of the gas, but they are apt to knock an electron from either electrode to start the train of ionization.

Ionization Chambers: An ionization chamber is a simple metallic cylinder filled with an inert gas, Fig. 23. An insulated rod is suspended from the center of one end plate. If the ionization chamber

RADIOACTIVE TRANSDUCERS

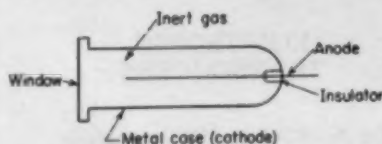


Fig. 22—A Geiger-Mueller tube for detecting the presence of beta particles.

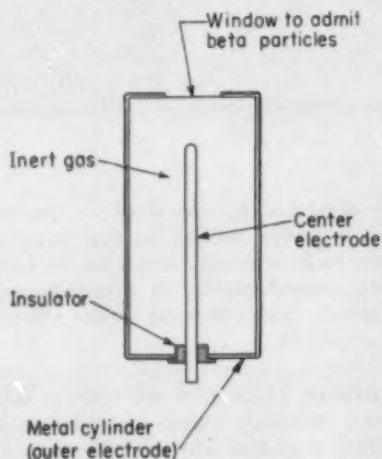


Fig. 23—Ionization chamber with a special type of window for indicating the presence of beta particles. Without a window, the chamber can be used to detect gamma rays.

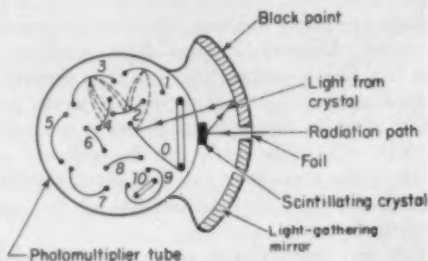


Fig. 24—Scintillation counter for use in detecting alpha and beta particles and gamma rays. Black point on the exterior surface of the mirror excludes extraneous light. Elements in the multiplier tube are: Element 0, cathode; elements 1-9, dynodes; element 10, anode.

is to be used to detect beta particles, a window is included in the end opposite the rod or on the cylinder wall, depending upon the application. An ionization chamber can thus be used to detect both gamma rays and beta particles. Alpha particles cannot pass through any window strong enough to contain the inert gas.

A difference in potential is maintained between the metal cylinder and the center electrode. Although an ionization chamber will operate with either polarity applied to the center rod, assume

that the center electrode is grounded through a high resistance and that the metal cylinder is maintained at +400 v. As beta particles enter the window, they strike molecules of inert gas and cause ionization. Negative ions are attracted to the wall of the cylinder, and positive ions are attracted to the center electrode. The positive ions collecting on the center electrode increase its dc potential. With the use of a dc amplifier, this small difference in potential can be measured. The change in potential is a function of the number of beta particles that enter the chamber and cause ionization.

Scintillation Counters: Operation of scintillation counters is based on certain materials which, when exposed to radioactivity, sparkle or scintillate. This sparkle is of sufficient magnitude to be picked up on a sensitive multiplier phototube and transformed into electrical impulses.

In a scintillation counter, Fig. 24, radiation en-

ters the crystal chamber, strikes the crystal, and causes it to sparkle. This light is picked up in the reflecting mirrors, passes through the wall of the multiplier tube, and is directed to the photocathode. The output of the tube is proportional to the amount of radiation striking the crystal and the amount of sparkle from the crystal. In this case, the true transducer is the material which sparkles, producing another physical condition, light. This light is then measured by a second transducer operating on the photoelectric principle.

Among the more brilliantly scintillating materials are crystals of anthracene, sodium iodide, stilbene, and zinc sulfide. Because crystals will scintillate to all three types of radiation, scintillation counters provide one of the more sensitive and efficient radiation-detection devices. Differently designed heads for the counter are used to distinguish between each of the various types of radiation. However, the Geiger-Mueller tube is used for high radiation levels.

MEASURABLE PHYSICAL PROPERTIES

Measurement or detection of various physical properties can provide necessary information or initiate some subsequent action. This measuring or sensing ability is a requirement for automated processes. Listed here in alphabetical order are different physical characteristics and the types of transducers that can be used to measure them.

ACCELERATION

Acceleration is the rate of change of velocity and may be either linear or angular. Acceleration is expressed in g's. One g, the acceleration of a free-falling body under the pull of gravity, equals 32.2 ft per sec per sec. Devices which measure acceleration—accelerometers—may use resistive, capacitive, magnetic, or piezoelectric transducers. Modern accelerometers are seismic devices which contain a known mass of material, a spring, and a transducer, Fig. 25. Under acceleration the mass tends to remain stationary and transmits a force through the spring to the transducer, which produces or varies an electric current. The force needed to accelerate the known mass is determined by the spring constant; thus, spring compression is proportional to acceleration. The accelerometer output is a signal corresponding to spring deflection. The output may be recorded on a scale calibrated in g's or may be used to trigger an alarm or switch if a preset maximum or minimum acceleration is exceeded.

ALTITUDE

Measurement of altitude depends upon atmospheric pressure—the greater the altitude, the lower the pressure. See *Pressure*.

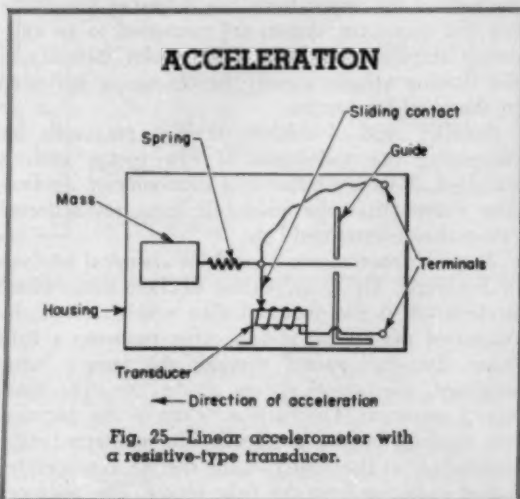


Fig. 25—Linear accelerometer with a resistive-type transducer.

COLOR

Color is a study of light. Color measurements for density or spectral value (wave length) are made with photoelectric cells or photomultiplier tubes, with or without the aid of optical systems.

Units for measuring color densities—densitometers—are widely used in color photography and printing. They are based on the transmission of light through a sample as compared with a known specimen or standard, Fig. 26. The transmitted light is received by a photocell, and the output of the cell is a measure of the color density.

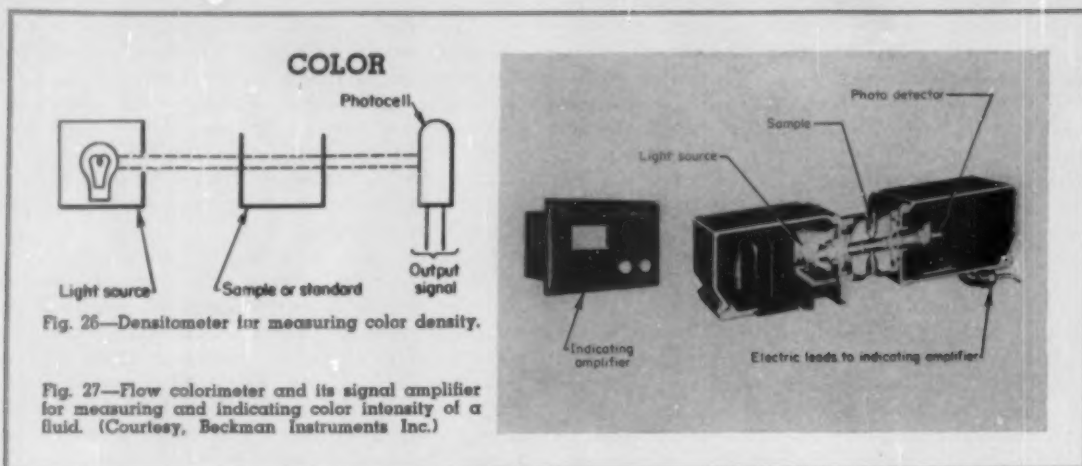


Fig. 26—Densitometer for measuring color density.

Fig. 27—Flow colorimeter and its signal amplifier for measuring and indicating color intensity of a fluid. (Courtesy, Beckman Instruments Inc.)

Colorimeters use photocell detectors to measure the color intensity of a product by the wave length of light striking the photocell. A typical flow colorimeter, Fig. 27, consists of a light source, a filter, a detector (photocell), and a measuring system. The length of the light path in the unit (called the cell), this filter to produce a proper wave length, and a detector for that wave length are chosen on the basis of the application. The output of the photocell and measuring system are connected to an indicating amplifier assembly. If the color intensity of the flowing sample varies, the change is indicated in the amplifier section.

Another type of colorimeter uses photocells for comparing the yellowness of raw cotton with a standard. This is similar to a densitometer application except that the photocell measures reflected rather than transmitted light.

A spectrophotometer is used for chemical analysis of materials. The only portion of these units which is electronic is the photocell tube which receives the output of the optical system. After receiving a light beam that has passed through the sample being analyzed, the optical system divides the light beam into a spectrum. The various values of the spectrum are received by the photocell. The spectrum varies depending on the ability of the sample to absorb infrared radiation from the light source. The photocell output is recorded as a spectrograph analysis.

COUNTING

Items in a production line can be counted with capacitive, magnetic, or photoelectric transducers. Counting with capacitive and magnetic units requires that the items be metallic, such as tin cans. With capacitive units, items being counted are used as one plate of the capacitor. A variable reluctance type of magnetic transducer counts items as they move into the field of the electromagnet. The flux density is varied, changing the current in the coil, and the pulse is transmitted to an electric counter. These units are the basis of proximity pickup systems.

Photoelectric transducers can be used with either metallic or nonmetallic materials. A photoelectric counting operation can be used as a packaging control, Fig. 28. Containers on a conveyor belt are placed so that the products being discharged from a hopper interrupt a light beam to a photocell. The interrupted signal is sent to a preset counting unit. When the required number of products have been deposited in the container, the preset counter activates the device controlling the gate and permits the filled container to move along the conveyor. An empty container then moves into position and the cycle repeats.

DENSITY

Liquid density can be measured by a magnetic

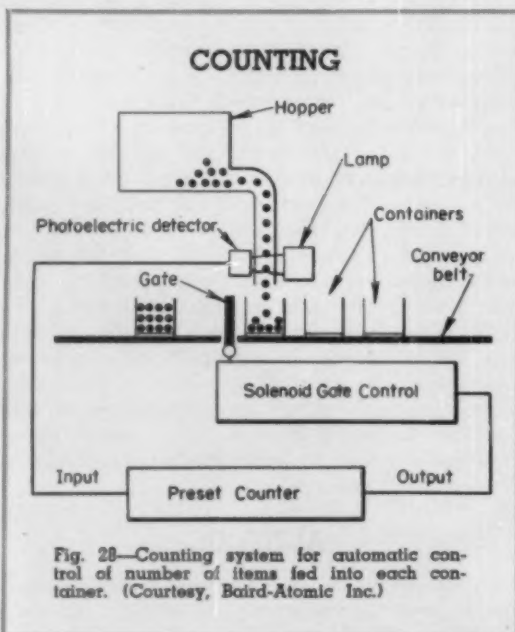


Fig. 28—Counting system for automatic control of number of items fed into each container. (Courtesy, Baird-Atomic Inc.)

DENSITY

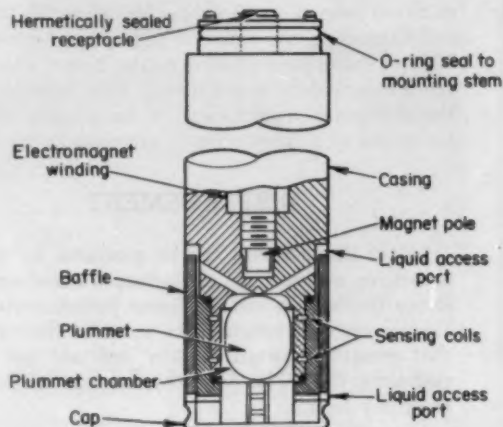


Fig. 29—Magnetic transducer in a probe which is used to measure liquid density by means of a null balance. A power unit and indicator or recorder are electrically connected to the probe. (Courtesy, General Communication Co.)

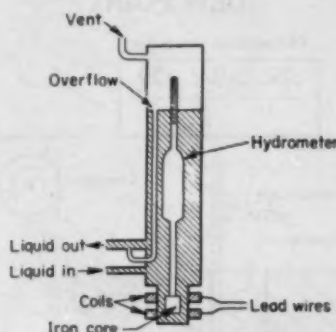
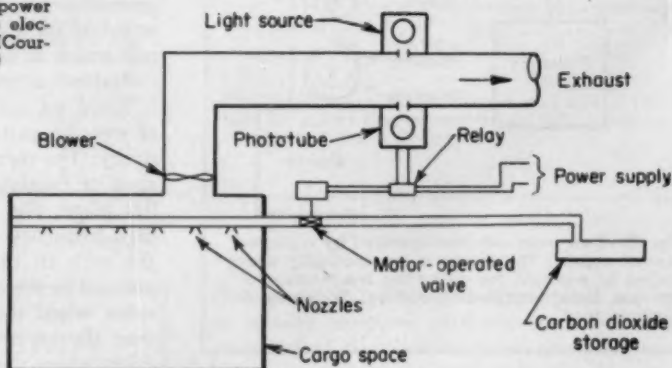


Fig. 30—Mechanical operation of a magnetic transducer for measuring liquid density.

Fig. 31—Photoelectric transducer for detecting smoke and automatically energizing a fire-extinguishing system on a naval vessel.



transducer housed in a probe, Fig. 29. The end of the probe contains a plummet magnetically suspended between two position-sensing coils. The suspending force is supplied by an electromagnet above the plummet. The two coils operate on a differential inductance principle using radio-frequency excitation. At the standard or null position, the coil outputs are similar. As a liquid of increased density lifts the plummet, a signal is fed to the power unit which decreases the current to the electromagnet. Reduced electromagnetic force allows the plummet to fall until it reaches the null position. The amount of current necessary to suspend the plummet at this position is proportional to the density of the liquid. A recorder or indicator reads the current directly in units of liquid density.

Density of liquids can also be measured by connecting a mechanical sensor to a magnetic transducer. In Fig. 30, an iron core is attached to the bottom of a hydrometer. Two coils are located outside the container opposite the iron core. As the hydrometer rises or falls with density changes, the

iron core changes inductance in the coils.

Radioactive transducers are also used for measuring density. A radioactive source is placed on one side of a material-conducting pipe, and an ionization chamber is placed on the opposite side. A variation in the density of the material flowing in the pipe varies the amount of radiation reaching the transducer. The denser the material, the more radiation it absorbs, and the less radiation reaches the transducer. The density of practically any gas, liquid, or slurry can be measured in this manner. Beta-radiation sources are most suitable for this type of measurement, but gamma sources are sometimes necessary for the measurement of the denser materials. The Atomic Energy Commission has established safety standards and training courses for operating and maintenance personnel for this type of equipment.

Density of smoke can be detected by photoelectric transducers of the photoemissive or photoconductive type, Fig. 31. If smoke enters the conducting tube, the amount of light striking the phototube is de-

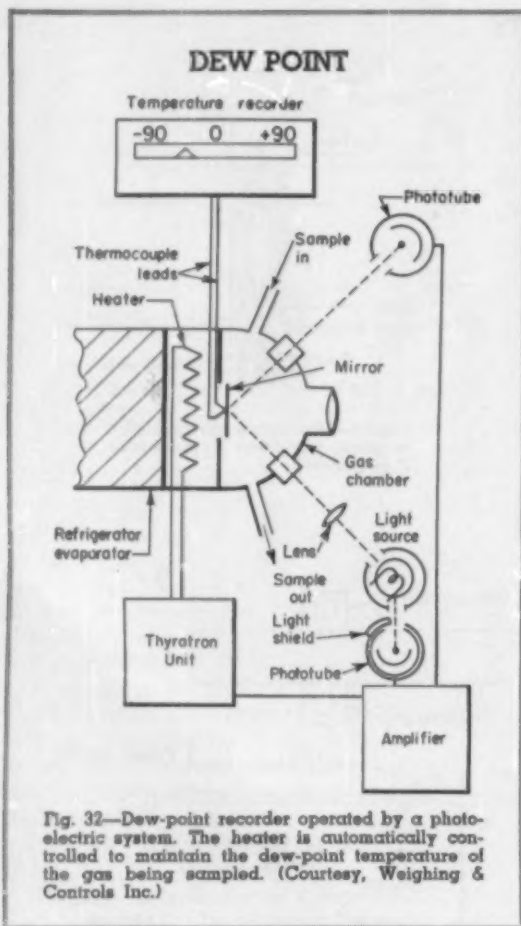


Fig. 32—Dew-point recorder operated by a photoelectric system. The heater is automatically controlled to maintain the dew-point temperature of the gas being sampled. (Courtesy, Weighing & Controls Inc.)

creased. Units of this type are used on naval vessels to detect fires in cargo spaces. The phototube output can be used to sound alarms or to turn on liquid or carbon dioxide fire-extinguishing systems.

DEW POINT

Dew-point temperature is the temperature at which water vapor condenses to a liquid. With determination of this point and the aid of a psychrometric chart, the moisture content of a gas can be calculated.

A unit for the continuous recording of dew-point temperature is shown in Fig. 32. Refrigerant at -90°F is supplied continuously to one side of a mirror. A constant stream of sample gas is passed over the other surface of the mirror. Coils of an electric heater mounted directly behind the mirror are capable of raising the mirror temperature from -90°F to ambient.

A light beam is focused on the mirror and reflected into a phototube. The amount of reflected light depends on the condensation on the mirror surface. The light beam is also focused on a second phototube to standardize against voltage variations. The outputs of the two tubes are connected to an ampli-

fier where they are compared. The difference in current controls the heater current by means of a thyatron.

The refrigerant gradually cools the mirror until moisture from the sample gas condenses on the mirror, decreasing the reflected light to the phototube. This increases current flow to the heater and causes the condensation to evaporate. This balance point, the dew-point temperature, is continually recorded by means of a thermocouple attached to the mirror.

DISPLACEMENT

Linear displacement can be measured by resistive, capacitive, magnetic, or photoelectric transducers. Resistive transducers are the linear-potentiometer type. Displacement is measured in terms of the resistance that remains between a slider and one end of the resistance wire. The potentiometer can be made almost any length.

Capacitive units, in which the distance between the two plates of the capacitor is varied, are used for relatively small displacements. Magnetic units are generally the inductance type where the core is mounted on a movable member and displaced in a coil which is mounted on the fixed member.

Another magnetic unit for measuring displacement is based on the inductive coupling between a pair of metallic patterns, which may be either linear or rotary. The metallic patterns are precisely spaced on glass or insulated metal plates and form coils in a flat plane, Fig. 33a. A slider unit is connected to a high-frequency current. As the slider is moved over the coils in the stator unit, a variable current is induced in the coils of the stator. Maximum coupling exists when the slider coils are positioned directly over the stator coils, Fig. 33b. Minimum coupling exists when the slider coils are spaced midway between the coils of the stator, Fig. 33c. When incorporated with control elements, the system is used for tape control and positioning of machine-tool operations.

Photoelectric units are used for measurement of large displacements. When combined with optical devices, they can also be used for measuring minute displacements, Fig. 34. The optical systems use diffraction gratings which have been made with up to 30,000 lines per in. A light is placed behind the grating. As the grating is moved, light passes through an optical slit and is picked up on photocells. Pulses from the photocells are counted, and the number of counts represents the linear displacement. This system is used in the control and operation of machine tools.

ELECTRICAL CONDUCTIVITY

This terminology applies to measurement of chemical concentration of solutions. Often called solution conductivity, or just conductivity, it is based on the electrical resistance of a solution to a flow of alternating current between two electrodes immersed in the solution. It can also be defined as the ability of the ions present in the solution to conduct an

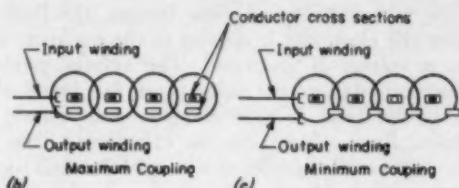
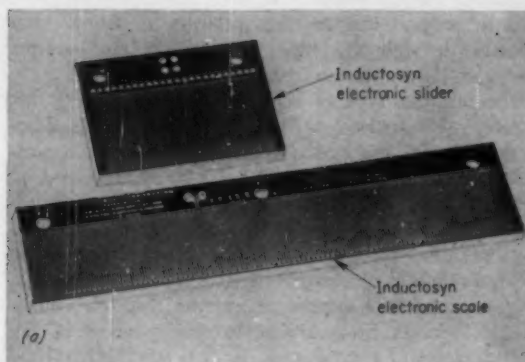


Fig. 33—Slider and scale elements for measuring linear displacements. a. (Courtesy, Farrand Controls Inc.) Maximum current is induced in the output windings (scale, or stator) when the slider wires, carrying high-frequency current, are directly over the stator wires, b. Minimum coupling exists when the slider wires are located midway between the stator wires, c.

DISPLACEMENT

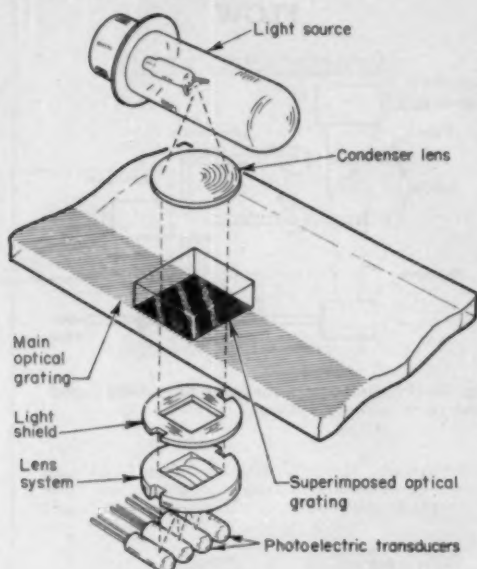


Fig. 34—Photoelectric transducers and optical system for measuring minute linear displacements. (Courtesy, Ferranti Electric Inc.)

ELECTRICAL CONDUCTIVITY

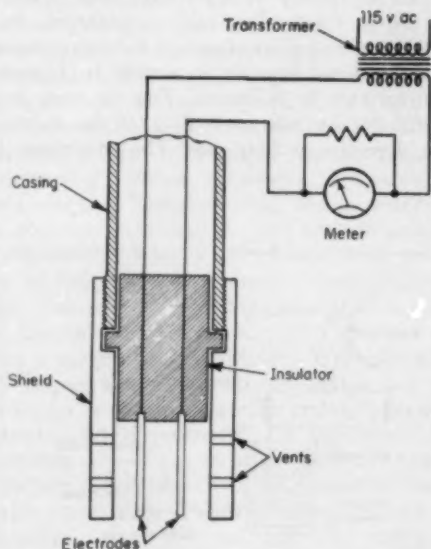


Fig. 35—Conductivity cell and circuit for measuring electrical resistance of solutions.

electric current. The unit of electrical conductivity or specific electrical conductance is the mho—the reciprocal of electrical resistance, the ohm.

In a typical conductivity cell, Fig. 35, electrodes, generally made of platinum, are spaced a fixed distance apart. Such cells are used to measure chemical composition of water solutions, such as salt or acid solutions; to check distilled or demineralized water or boiler condensate; to measure the extent of chemical reactions; or to detect contaminations in solutions.

FLOW

Flow can be measured with photoelectric, magnetic, and thermoelectric transducers. The flow of a process liquid is controlled in Fig. 36 by a photoelectric arrangement. A rotameter float is adjusted to the rate of flow desired for the process. If the flow varies such that the float intercepts one of the light beams, the corresponding phototube output can be used to actuate a relay which controls a valve in the feed line.

A magnetic transducer of the inductance type is shown in Fig. 37. A rotor containing a small permanent magnet is installed in a pipeline. The pick-up coil is installed outside the pipe. As flow in the pipe causes the rotor (and magnet) to turn, a pulsating current is set up in the external coil. The number of pulses generated by the sensing element is di-

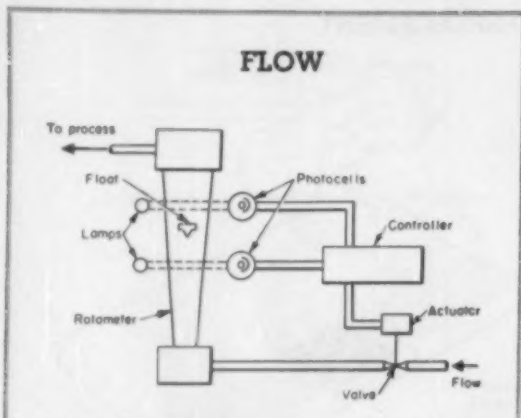


Fig. 36—Photoelectric transducer controlling liquid flow in a process system.

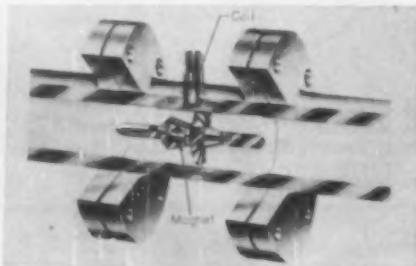


Fig. 37—Inductance-type transducer which produces electrical pulses proportional to liquid flow in a pipe. (Courtesy, Potter Aeronautical Corp.)

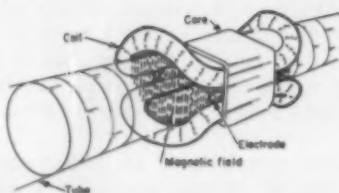
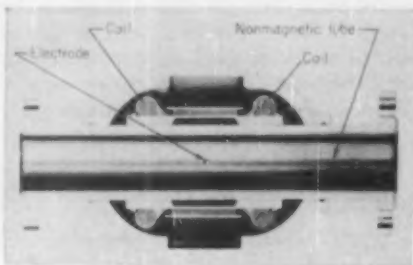


Fig. 38—Magnetic flow transmitter which induces a voltage in a conductive fluid as it flows through a magnetic field. (Courtesy, The Foxboro Co.)

rectly proportional to the quantity of liquid that passes through the pipe. The pulses are counted with an electronic counter.

In another type of magnetic flowmeter, Fig. 38, there is no restriction inside the pipe. Two saddle-shaped coils straddle the pipe and furnish a uniform magnetic field. This field is concentrated at right angles to the flowing fluid by a laminated iron core.

Operation of the unit (transmitter) is based on Faraday's law of electromagnetic induction—a voltage induced in a conductor moving through a magnetic field is proportional to the velocity of the conductor. The conductor is the conductive fluid between the electrodes, and the conductor length is the tube diameter. At any instant, the fluid between the electrodes is moving in the magnetic field, and a voltage is generated. The voltage produced is proportional to the velocity of the liquid flowing in the tube. If tube diameter and velocity are known, flow volume can be calculated. This volume is generally computed in a recorder and recorded on a chart. Units of this type are useful for handling corrosive solutions or liquids containing dirt or large particles.

Flow in open flumes or troughs can be measured by floating a sensor on the hydraulic head in a stilling chamber, Fig. 39. The head is created by a weir or Parshall flume. As flow increases, the level increases, raising the float. The float can be attached to the core of a mutual inductance coil to produce a signal which is transmitted to a remote location and recorded.

Thermistors are also used for measuring flow in pipes or open flumes. The thermistor, inserted in the pipe or flume and submerged in the liquid, is heated by passing a current through it. When there is no flow in the pipe, the surrounding liquid cools the thermistor at a uniform rate. When the liquid flows, the cooling rate is increased. As the thermistor is cooled, its electrical resistance increases. The proportional decrease in current is proportional to the increase in resistance. This, in turn, is proportional to the rate of cooling of the thermistor, which depends on flow rate. The thermistor leads

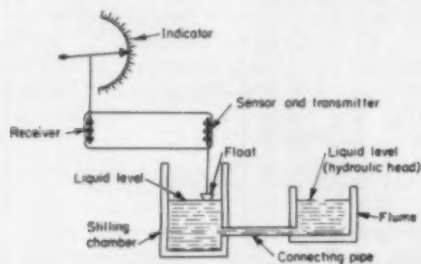


Fig. 39—Measurement of liquid flow rate in an open trough by means of a sensing device attached to a float.

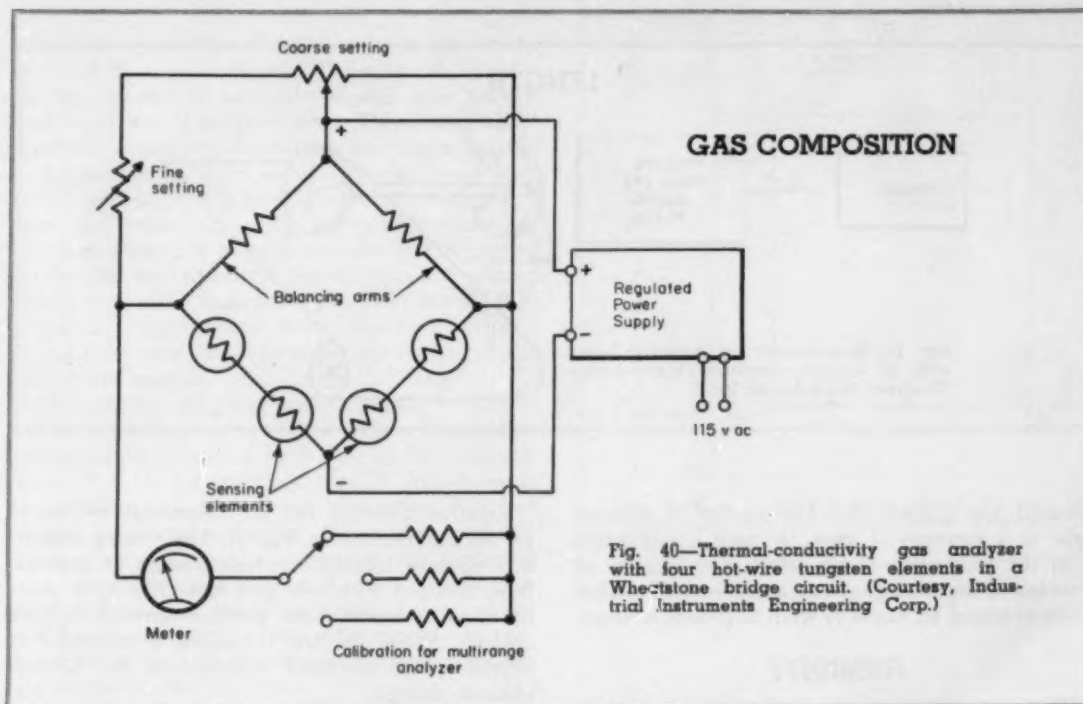


Fig. 40—Thermal-conductivity gas analyzer with four hot-wire tungsten elements in a Wheatstone bridge circuit. (Courtesy, Industrial Instruments Engineering Corp.)

are connected to an indicator or recorder, or are connected to a controller which can control the flow rate.

GAS COMPOSITION

In addition to the infrared (and ultraviolet) spectrophotometer described under *Color*, gas analysis is also made with a resistive transducer in the thermal-conductivity or hot-wire method. The theory of determining gas-purity percentages by thermal conductivity is based on two facts: 1. Each specific gas has an individual heat-transmission factor. 2. Certain metals have a fixed temperature-resistance relation.

The sensing element of a thermal-conductivity gas analyzer is a filament or coil of fine wire, generally platinum or tungsten. The wire is mounted in a chamber to form a cell. Several cells are installed in the Wheatstone bridge circuit shown in Fig. 40. One arm of the bridge is used as a standard or reference-sensing element with a second arm used as a sample-sensing element. With a suitable electric current flowing through the bridge, and with the same gas or gas mixture surrounding each sensing element, equal resistances are developed. If a different gas or mixture is introduced to a sample cell, the sensing element will be heated or cooled to a new temperature because of the different heat-transmission rate of the new gas. The change in temperature of the sensing element changes the resistance of the bridge arm. This resistance change unbalances the bridge, permits a current to flow, and provides an accurate indication of the purity of the gas surrounding the sampling element.

GLOSS

Photoelectric transducers are used to measure gloss or reflectance of various materials. Gloss measurements and standards have been established for paints, plastics, paper (coated and uncoated), and porcelain enamels—all based essentially on the same procedure. Light is beamed on the material being tested and

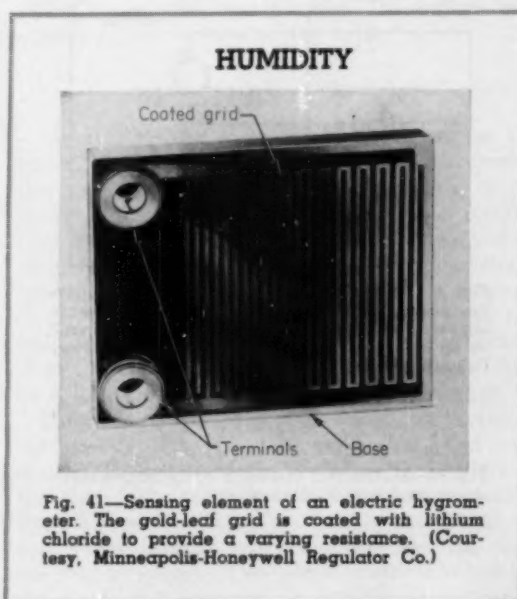


Fig. 41—Sensing element of an electric hygrometer. The gold-leaf grid is coated with lithium chloride to provide a varying resistance. (Courtesy, Minneapolis-Honeywell Regulator Co.)

LENGTH

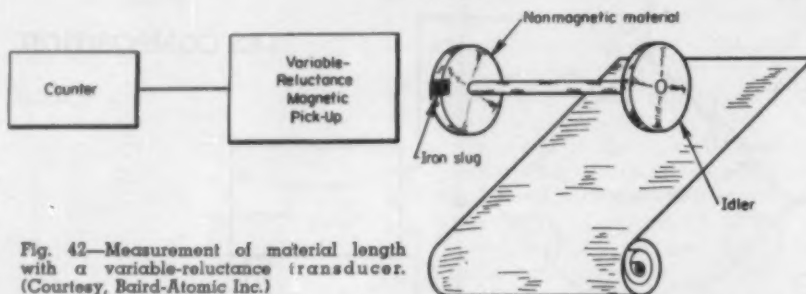


Fig. 42—Measurement of material length with a variable-reluctance transducer. (Courtesy, Baird-Atomic Inc.)

reflected into a phototube. The amount of reflected light is a measure of gloss. A typical application is in the production of tile where any increase or decrease of the final gloss can actuate reject mechanisms or sound an alarm to warn of process changes.

HUMIDITY

The common measure for moisture content of air or any gas is relative humidity, which is the ratio between the water-vapor content of a gas and the water-vapor content which would saturate the gas at the same temperature.

Relative humidity can be determined by use of an electric hygrometer, Fig. 41. The sensing element is a resistive transducer which consists of a plastic form stamped with two gold-leaf grids. The overall form is coated with moisture-sensitive lithium chloride. When the unit is exposed to variations in humidity, the electrical resistance of the lithium chloride changes.

LENGTH

Continuous lengths of material can be measured by using a magnetic transducer of the variable-

LEVEL

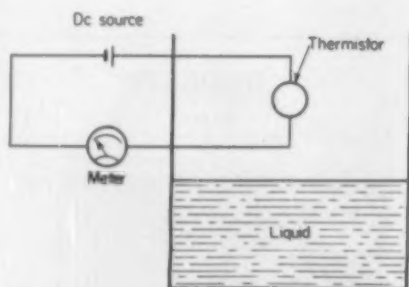


Fig. 43—Use of a rising liquid level to increase the cooling rate of a heated thermistor. The resulting increase in thermistor resistance can be used as an indication of liquid level. (Courtesy, Victory Engineering Corp.)

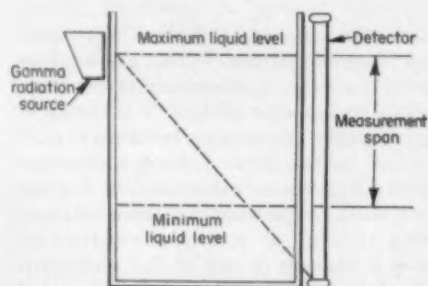


Fig. 44—Radioactive transducer for continuous measurement of liquid level. (Courtesy, Industrial Nucleonics Corp.)

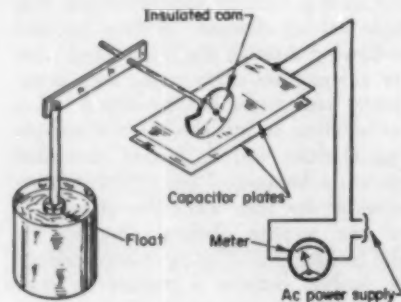


Fig. 45—Mechanical operation of capacitive transducer as liquid level changes.

reluctance type, Fig. 42. Two wheels are firmly attached to a common axle. The idler wheel rides on the material to be measured and must have a high coefficient of surface friction. The sensing wheel is usually plastic and contains an iron slug embedded in its periphery. As the material is moved, the idler rotates and causes the sensing wheel to rotate. Each time the iron slug passes a variable-reluctance magnetic pickup, a pulse is initiated and registered on the counter. Proper sizing of the idler and sensing wheels can make each pulse represent inches, feet, yards, etc. High speeds, with little wear of parts in the transducer and with negligible loading of the system, are possible.

Differences in length of material caused by shrinking or stretching, as in textile or paper manufacturing, can be measured by the use of two magnetic transducers of the generator type. A transducer is mounted at each end of the production line and rotated by idlers resting on the moving material. The outputs of the two generators are connected to a zero-center galvanometer. If either transducer is rotating faster than the other, a difference in voltage will be recorded. This voltage difference can be calibrated to indicate the percentage of stretch or shrinkage of the material in process.

LEVEL

Measurement of liquid level may be made by the same means described under *Displacement*, since a change in level is equivalent to displacing the top surface of the liquid.

Other methods are also used. The resistive transducer shown in Fig. 4 can be used to measure the level of a conducting solution. A thermistor or thermoelectric transducer can be inserted in a vessel to detect level changes, Fig. 43. Since liquid conducts heat faster than air, rising liquid covers the thermistor and lowers its temperature. Resistance of the thermistor increases and decreases the current flow.

Radioactive systems for level control use a minute quantity of radioactive material which emits gamma rays, Fig. 44. As the level rises, the number of gamma rays reaching the detector decreases. The output of a Geiger-Mueller tube, used to detect the number of rays passing through the liquid, can be calibrated for liquid level.

In an industrial application of a capacitive transducer for level measurement, Fig. 45, the lower capacitor plate is fixed. The upper plate, free to move, is positioned by an insulated cam. As the level in the tank rises, the linkage rotates the cam, allows the plates to separate, and decreases current in the capacitor circuit. The meter can be calibrated to read in gallons or in feet of depth.

Photoelectric transducers can be used as level controls by passing a light beam across a tank. When the level rises and interrupts the light beam, the current in the phototube is cut off and causes a normally open relay to close. The relay operates an actuator (valve) which shuts off flow to the tank.

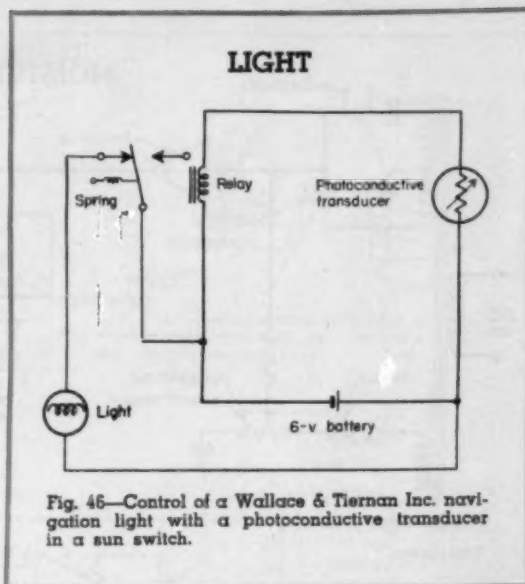


Fig. 46—Control of a Wallace & Tiernan Inc. navigation light with a photoconductive transducer in a sun switch.

LIGHT

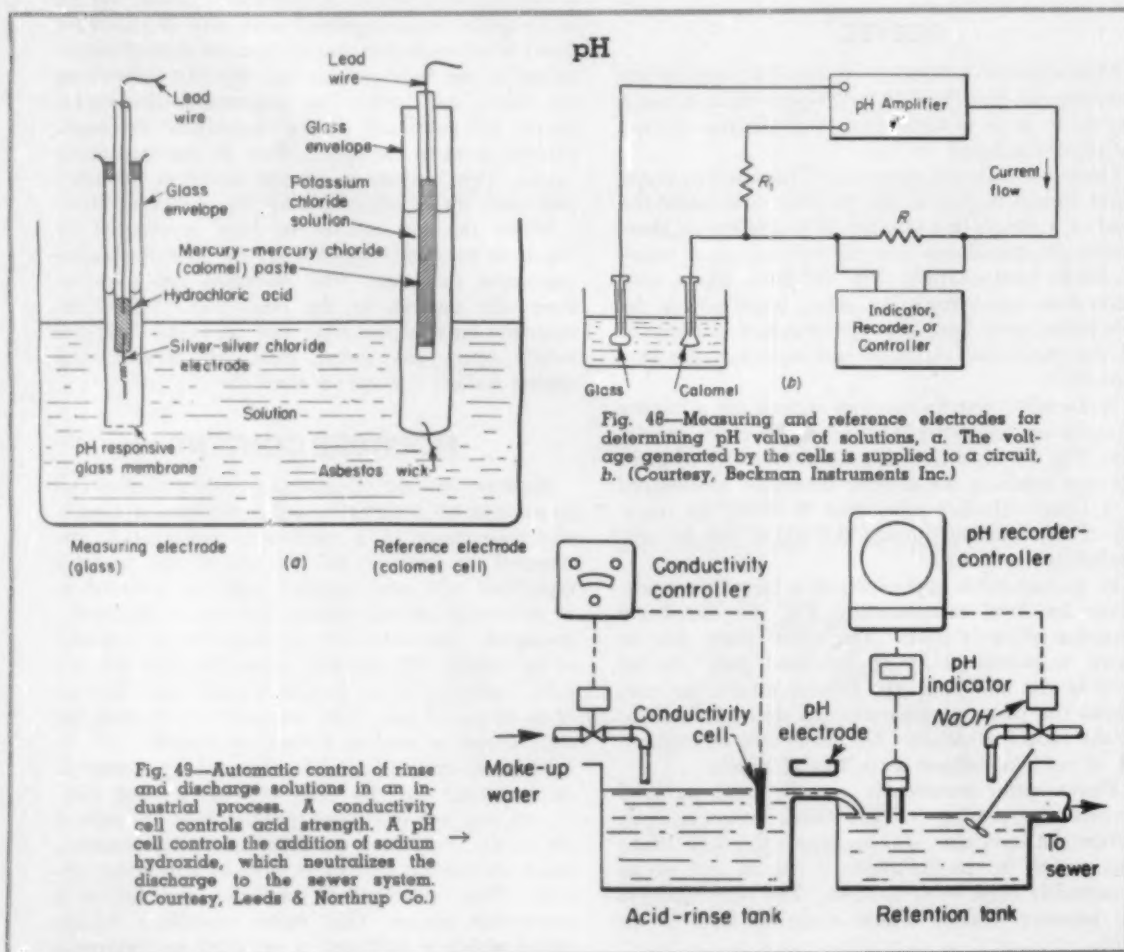
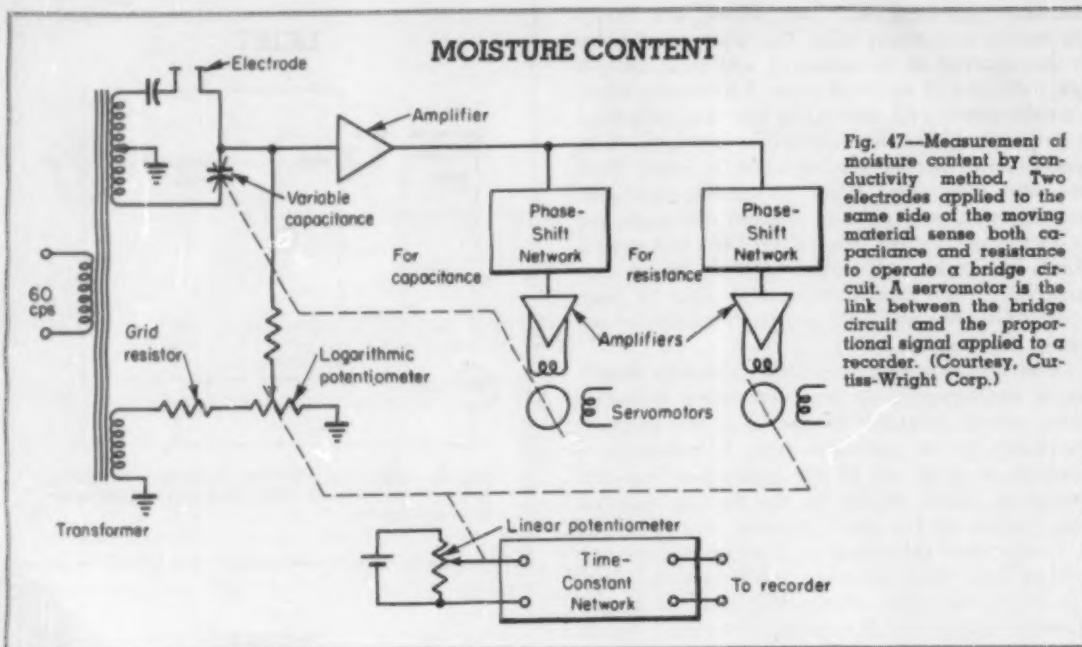
The measurement of light intensity, either visible or invisible, is accomplished with any of the three types of photoelectric transducers. A typical application is the sun switch, Fig. 46. As light from the rising sun strikes the photoconductive transducer, the resistance of the transducer decreases, permitting more current to flow in the transducer circuit. This increase in current energizes the relay and opens the circuit containing the navigation light.

When the sun sets or its light is reduced by clouds or fog, the resistance of the photoconductive transducer increases. The increased resistance reduces the current to the relay coil. When the magnetic force of the relay can no longer hold the switch open, the spring closes the switch, and applies battery voltage to the light.

MOISTURE CONTENT

Moisture content of materials, mainly textiles and paper, can be detected by either resistive or capacitive transducers in a continuous sampling of the material in process. In the use of the resistive type, two rolls turn together with the material to be measured between them. One roll is electrically grounded. The other roll is connected to a source of dc voltage. As material passes between the two rolls, resistance to the flow of current varies because of moisture content. This variation can be recorded on a graph or used as a moisture control.

Moisture content is also measured by means of conductivity, Fig. 47. The measuring head containing the two electrodes contacts only one side of the sheet. Variations in moisture content cause a small alternating current to flow in the bridge circuit. This unbalance is amplified and fed to a servomotor system. One motor controls a voltage signal which is indicated or recorded as percentage



PRESSURE

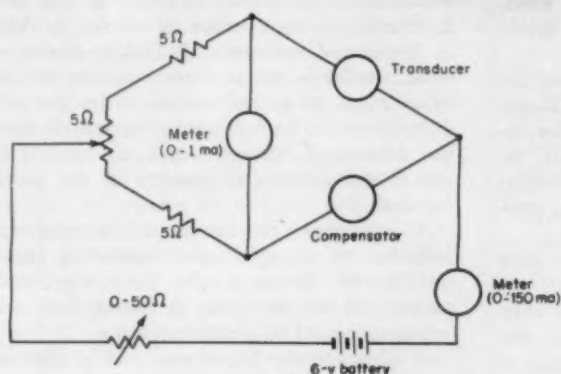


Fig. 50—Hot-wire resistance transducer in a bridge circuit for measuring pressure. (Courtesy, Sylvania Electric Products.)

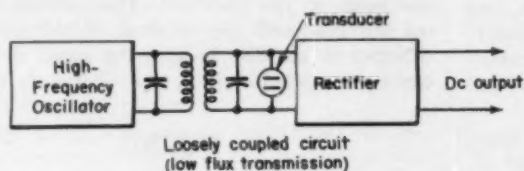


Fig. 51—Measuring pressure with a capacitive transducer which varies the voltage into a rectifier.

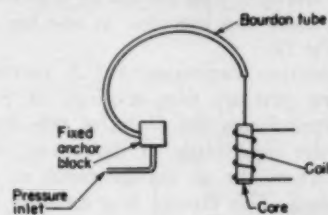


Fig. 52—Mechanical actuation of core of an inductance coil for measuring fluid pressure.

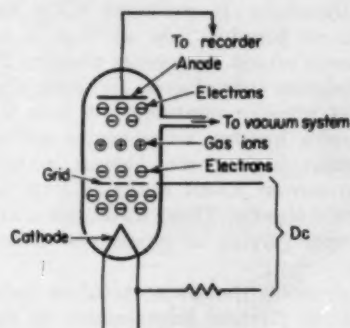


Fig. 53—Ionization gage for measuring a vacuum.

of moisture content of the material as it moves past the two electrodes.

In a capacitance-type moisture meter, the material being measured is passed between the plates of a capacitor energized with ac voltage from an rf oscillator. Variations in moisture vary the dielectric constant of the capacitor, and the change in capacitance can be measured on a capacitance bridge.

pH

Measurement of pH, the term used for acidity or alkalinity of solutions, is not accomplished with any of the specific transducers discussed here. The devices used, however, are classed with the family of resistive transducers since conductivity or resistivity of solutions is involved.

The acidity or alkalinity of a solution depends on the relative concentration of hydrogen and hydroxyl ions present in the solution. The solution is acidic if hydrogen ions predominate and alkaline if hydroxyl ions predominate. The sum of the two types of ions is a constant value, and pH is determined by measuring the hydrogen ions with an electrolytic cell generally consisting of a glass electrode and a reference electrode, Fig. 48a. The two electrodes are sensitive only to hydrogen ions. When the electrodes are immersed in a solution and the lead wires are connected, a flow of current is produced, as in a battery. The amount of voltage generated is

proportional to the hydrogen ion concentration. In the electrical circuit, Fig. 48b, resistance R_1 is used partially to balance the voltage generated by the cell and to minimize the flow of current. If a high current is allowed to flow in the cell, the electrodes will polarize and will upset an accurate determination of pH.

The control of pH is necessary for many manufacturing processes and also has application in disposal of wastes from such processes as plating and soldering. A typical system, Fig. 49, uses water for rinsing acid from parts being prepared for soldering. When the acid solution in the rinse tank becomes too strong, make-up water is added, and the excess overflows to the retention tank. In the retention tank the pH cell measures the pH of the solution and, when required, causes sodium hydroxide to be added to neutralize the discharge to the sewer. This system minimizes the amount of make-up water and sodium hydroxide required.

PRESSURE

Measurement of pressure either above or below atmospheric can be made by almost all types of transducers. In the group of resistive types, strain gages are used. The hot-wire gage is another resistive transducer for measuring pressures below 1 mm of mercury absolute down to 1 micron of mercury. These gages operate on the principle that heat loss from a hot resistance wire varies as

pressure changes. The change in resistance is measured by using the hot wire as one leg of a bridge circuit, Fig. 50.

A capacitive transducer, Fig. 5, can be used for measuring pressure over a range of 1-10,000 psi. As pressure forces the plates of the transducer together, the capacitance in the circuit, Fig. 51, increases. Thus, the ac voltage input to the rectifier is decreased. This change is a measure of the pressure change.

A magnetic transducer can be used to sense pressure changes. The armature in an inductance coil (differential transformer) or a reluctance-type magnetic transducer is connected to a flexible diaphragm or bourdon tube so that it responds to movements caused by pressure changes, Fig. 52.

Piezoelectric transducers are generally used for transient pressure measurements from 0-10,000 psi in ballistics, blasting, rocket-engine testing, internal-combustion engines, etc. Crystal microphones are used to convert sound waves (a form of pressure) to electric signals. These waves are also of a transient type, varying as words are spoken into the receiver.

An electronic transducer called an ionization gage is used for pressure measurement in the range of 1 micron of mercury to absolute zero. This gage is a vacuum-tube device, Fig. 53. The grid is maintained positive with respect to the cathode to accelerate the electrons leaving the cathode. When the gas in the tube is at relatively high levels of pressure, the electrons leaving the cathode bombard the gas molecules, forming many ions. Electrons from both the cathode and the ionized gas are attracted to the anode. As a result, plate current is high. As the pressure is reduced, fewer molecules of gas are present, and less ionization takes place. Therefore, fewer electrons are available, and the plate current is less. Thus, plate current is a function of the amount of gas (pressure) in the tube.

ROTATION

Constant rotating motion of hundreds of revolutions per minute can be detected and controlled by a magnetic transducer of the generator type. At a specified speed, the generator produces a certain voltage output. Any increase or decrease in speed changes the voltage output accordingly. This voltage can be connected to voltage-sensitive relays or subsequent devices to control speeds of motors in production of paper, textiles, sheet metal, and other processes.

Rotation can also be detected with a variable-reluctance unit by replacing the idler wheel in Fig. 43 with a rotating device. One unit operating on this principle is called a tone wheel. An iron or steel gear is placed on the rotating shaft. A variable-reluctance transducer pickup mounted 0.005 to 0.010 in. from the gear teeth generates an ac voltage as the teeth pass in front of the magnet-pole face. A unit of this type can be used for measuring very high speeds.

Rotation of low-speed units is generally detected with resistive transducers called potentiometers. Potentiometers can have: 1. High or low accuracy. 2. Variations in number of turns. 3. Variations in amount of resistance. 4. Linear, square root, or other similar outputs. Potentiometers are operated by rotation of a shaft which varies the resistance in a circuit. The amount of resistance determines the amount of current, which, in turn, is a measure of the amount of rotation of the potentiometer shaft.

A capacitive transducer can be used to detect rotation in an application similar to that shown in Fig. 45. However, the force supplied to the torque rod by the rising or falling float would be supplied instead by a rotating device.

A photoelectric transducer and a disc attached to a rotating shaft can be used to measure rotation. The disc, which must contain small holes or slots, is superimposed between a photocell and a light source. As the shaft turns, light passes through the holes to the photocell. The number of pulses on the photocell are counted. With the number of holes in the disc known, the speed of the shaft can be computed.

SOUND

Sound is the result of waves being transmitted through a medium—solid, liquid, or gas. The waves are oscillatory in nature and possess both length and amplitude. Wave length is a function of pitch, and amplitude is a function of intensity of the sound. Sound waves create pressure variations in the transmitting medium and can be sensed by pressure transducers. The primary transducers for converting sound energy to electrical energy are microphones.

SPEED

Measurements of speed, or velocity, can be made with magnetic, capacitive, photoelectric, piezoelectric,

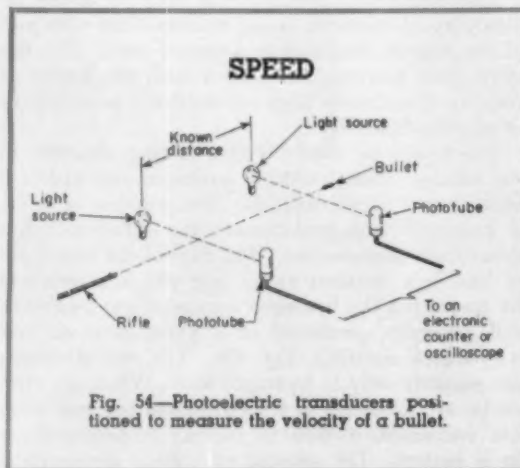


Fig. 54—Photoelectric transducers positioned to measure the velocity of a bullet.

and, in some cases, radioactive transducers. Generator-type magnetic units are usually mechanically coupled to the unit whose velocity is being measured. Velocity can be linear or angular depending on the mechanical linkage. (See *Rotation*.)

Variable-reluctance units can be used for linear or angular-velocity measurements by having a magnetic material pass through the field of an electromagnet. This is the same type of application as that used in Fig. 42 for counting. For velocity, the units are feet per second or feet per minute; for counting, the measure is total feet.

Capacitive transducers can be used for velocity measurement when one plate is stationary and the other plate is mounted in the item being checked. This method is generally suitable for rotating members. However, the plate on the rotating object must be connected to the circuit by means of a slip ring.

Capacitive units can also be used in missile and ballistics work to measure air speed. One plate, attached to a diaphragm, is deflected by air pressure. The other plate is fixed. The variation in the distance between the plates changes the capacitance of a circuit. This is the same principle used in the capacitor microphone.

A method using photoelectric transducers for velocity measurements is shown in Fig. 54. Two photocells and their individual light sources are set up a fixed distance apart. When the beams are interrupted by a passing object, each photocell emits a pulse. With the spacing between light beams known, the velocity of the moving object can be computed. The time interval between pulses is measured with an electronic counter or an oscilloscope.

STRAIN

Strain, generally in structures or structural members, is measured with resistive transducers. The most common type used is the strain gage shown in Fig. 1.

TEMPERATURE

Temperatures of solids, liquids, and gases are measured by direct contact with resistive or thermoelectric transducers. For indirect measurement of the temperature of molten metal, white-hot billets, and furnace interiors, transducers are built into resistance thermometers, pyrometers, and bolometers.

Disc-type thermistors are used in aircraft windshields to control by direct contact the amount of heat needed to prevent frosting. Bead-type units are used in nozzles of plastic extrusion presses to sense the temperature of the plastic so that it may be controlled at a constant temperature.

Radiosondes in balloons use thermistors to sense atmospheric temperatures. As thermistor temperature, and therefore its resistance, varies, the pulse time of radio transmission is varied. By measuring the transmitted pulse time, atmospheric temperature can be determined.

Thermistors can be used at considerable distance

TEMPERATURE

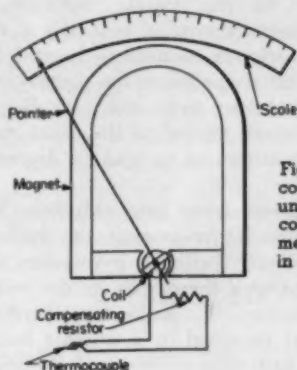


Fig. 55 — Thermocouple pyrometer unit with a moving-coil meter movement which rotates in a magnetic field.

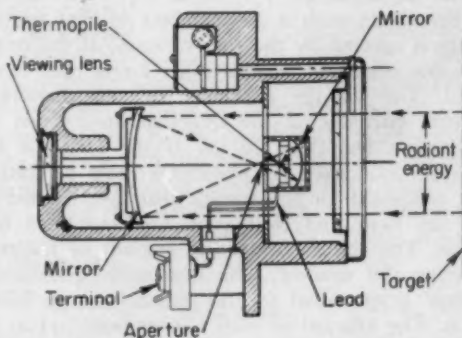


Fig. 56—Double-mirror type of radiation pyrometer. (Courtesy, Leeds & Northrup Co.)

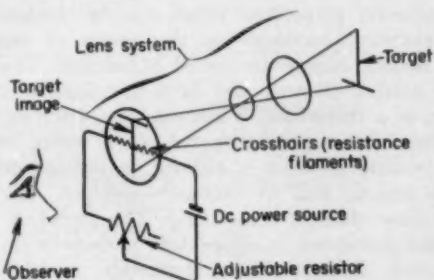


Fig. 57—Optical pyrometer for comparing a glowing filament with a hot source.

from the point of recording or control since the resistance of the leads has little effect on the circuit. Thermistors or thermoelectric transducers are used not only as direct temperature-measuring devices but also as control units to correct for ambient-temperature variations.

Resistive transducers for measuring temperature are generally the resistance-thermometer type which

contains a single fine-wire filament or a coil of fine wire.

Pyrometers may be the contact, radiation, or optical type. The contact type is generally a thermocouple or thermoelectric transducer housed in a shell or bulb. As heat is applied to the thermocouple junction of the pyrometer unit shown in Fig. 55, a voltage passes through the coil of the meter movement. The scale is calibrated to read in degrees of temperature.

Radiation pyrometers detect heat radiation. They measure temperature by measuring the radiation emitted from an object. Radiation pyrometers often use a thermocouple or a thermopile as the receiver for the radiant energy. To make the thermopile more efficient, it is mounted in a suitable housing with an optical system that collects and focuses the energy on it.

The double-mirror pyrometer, Fig. 56, is sighted on the target with a viewing lens so that the aperture is covered by the source image. If the image does not cover the aperture, the target area is too small. The voltage generated by the thermopile depends partially on the target distance when the distance is less than 20 in. If the target is less than 20 in. away, the pyrometer must be focused and calibrated for the specific distance. Beyond 20 in., the focus and calibration are considered universal. The shutter limits the amount of radiation entering the window. The thermopile generates a voltage proportional to the radiant energy falling on it. The amount of energy is proportional to the temperature of the target.

Radiation pyrometers are available for temperatures ranging from 200 to 3200 F, for large or small target areas, and for various speeds of response.

Radiation pyrometers which use the resistance of an electrical conductor as the means of measuring radiant energy are called bolometers. The specific sensing element may be a fine wire, a coil of wire, or a thermistor. A current, passed through the sensing element, is measured on a meter. When the sensing element is exposed to radiant energy, it is heated, and its resistance changes. The current flow changes accordingly. The recording scale of the bolometer is calibrated in degrees of temperature. Bolometers are extremely sensitive and have a fast speed of response, but they are not as rugged as thermocouple pyrometers.

Radiation pyrometers are also made with any of the three types of photoelectric transducers. Pyrometers using these transducers have the maximum speed of response but must be protected from overheating.

Optical pyrometers generally use resistive transducers and measure temperatures from 1400 to 5200 F. With special filters, the range can be extended to 10,000 F. Sufficient current is passed through the resistance filament to cause it to glow. By optical means, an image of the hot source is superimposed on the heated filament, Fig. 57. The observer, sighting the image and the filament, increases or decreases the current flowing in the re-

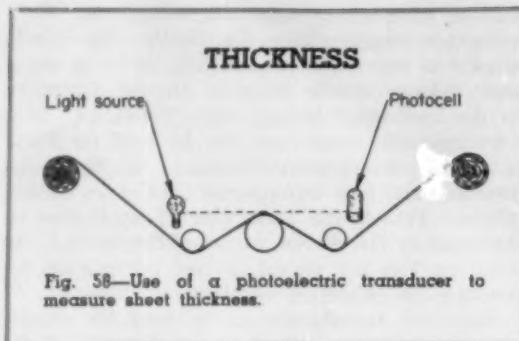


Fig. 58—Use of a photoelectric transducer to measure sheet thickness.

sistance element until the color of the heated filament matches the color of the hot-source image. The current required to make the filament glow at the brightness of the target is measured and is calibrated to read the temperature of the hot source.

THICKNESS

Thickness of metallic materials can be measured by magnetic, capacitive, photoelectric, and radioactive transducers. Textile or paper materials can be gaged by photoelectric and radioactive transducers.

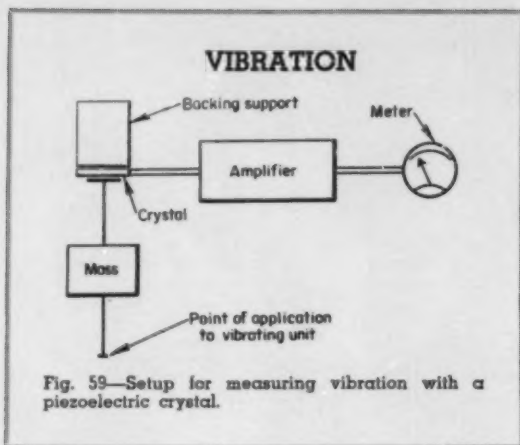
Inductance-type magnetic transducers are used by placing two electromagnets close to, but on opposite sides of, the metallic sheet being measured. Changes in the thickness of the material vary the mutual inductance of the system and vary the flow of current in the electromagnetic coils. Magnetic units of the reluctance type require only one electromagnet, but the results are the same.

Capacitive and magnetic units are generally suitable only for foil or relatively thin sheet metal. Heavy-gage material would require capacitor plates or electromagnets of prohibitive size.

A system of thickness control using a photoelectric transducer is shown in Fig. 58. The material being rolled is passed over a roller. A beam of light is adjusted to pass above the roller so that material of the desired thickness will partially interrupt the light beam. Any increase or decrease in thickness interrupts more or less of the light beam. The amount of light is measured by the photocell. The photocell output can be used to operate a controller to regulate the thickness automatically.

Radiation methods can be used for measuring thickness of metal, textile, or paper by interposing the material between a radioactive source of gamma or beta rays and an ionization chamber. The choice of a radioactive source is determined by the thickness of the material to be measured.

One type of radiation gage uses x-rays to measure thickness of materials. The x-ray source is mounted on one side of the sheet, and a photomultiplier tube, the sensor, is mounted on the other side. As the thickness of material increases, more rays are absorbed and less strike the multiplier tube. As thickness decreases, more rays strike



the sensor. The advantage of an x-ray device is the greater range of thicknesses which can be measured with the same source unit. More input voltage is applied to the source for thicker materials, and less voltage for thinner materials.

TURBIDITY

Turbidity is the condition of a solid suspended in a liquid. The best example is muddy water. Measurement of turbidity is made by projecting light through the solution into a photocell. As turbidity increases, the light reaching the photocell decreases, decreasing the output from the phototube. This output signal can be used to operate relays, which in turn start pumps or chemical-control equipment to treat the solution and reduce or increase tur-

bidity. Increased turbidity is required in the preparation of certain liquid concentrates.

VIBRATION

Vibration is most commonly measured with piezoelectric transducers. Other more complicated units for special applications, however, are available. Piezoelectric transducers are used by transmitting to a piezoelectric crystal the inertia of a mass acted on by the vibration, Fig. 59. The crystal produces a voltage output in proportion to the strain applied to it and operates on an ac frequency which is the same as the frequency of vibration.

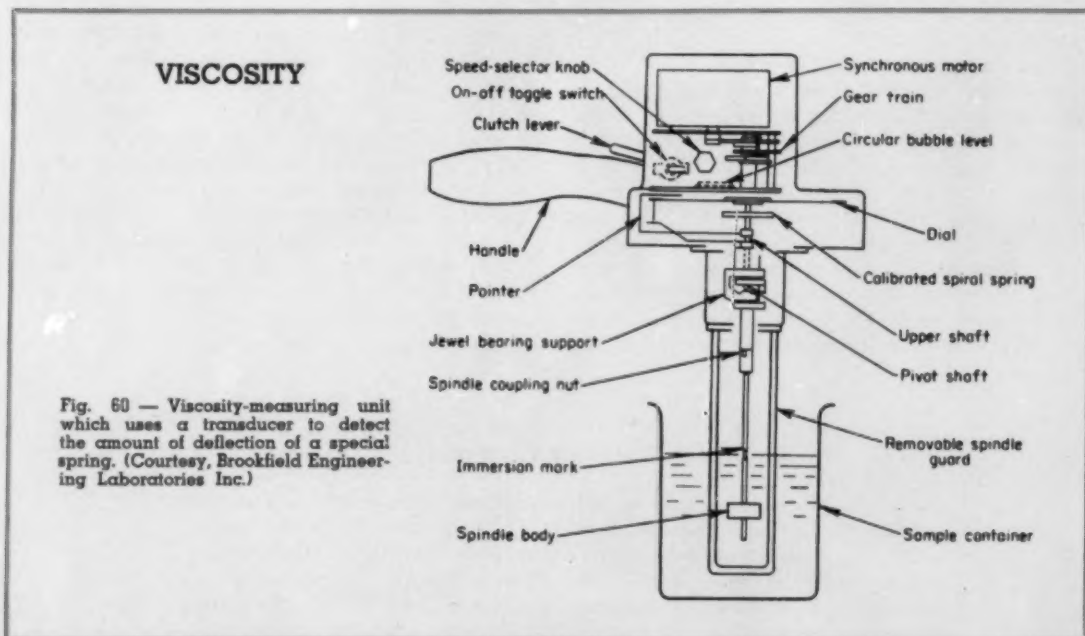
VISCOSITY

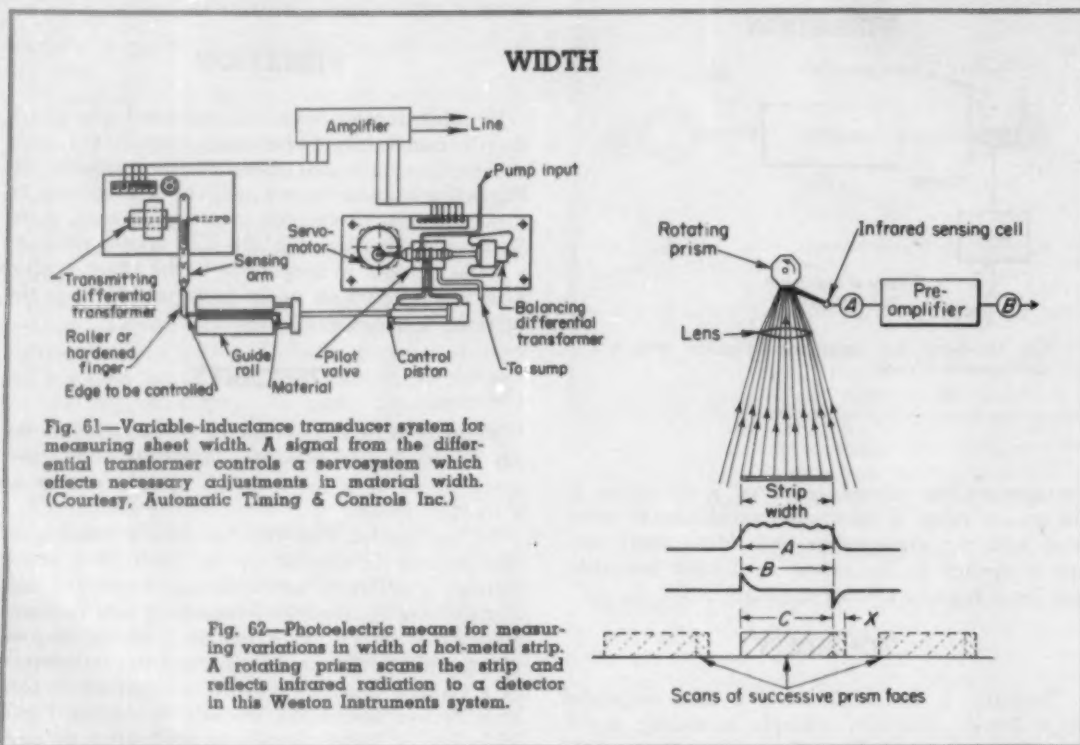
Viscosity of solutions can be measured with the aid of resistive or capacitive transducers. The primary sensor is a motor-driven spindle rotated at a constant speed.

In one model, Fig. 60, the spindle rotating in the material is coupled to the shaft of a motor through a calibrated beryllium-copper spring. Either a potentiometric (resistive) transducer or a variable-capacitance unit is used to detect the amount of spring deflection. A measurement of the capacitance of a variable capacitor provides a signal which controls devices that adjust viscosity by adding liquid of higher or lower viscosity or by heating or cooling the material.

WIDTH

Width of materials such as paper, textiles, metal, and glass can be measured by means of magnetic transducers of the variable-inductance type, Fig. 61.





A roller mounted on a lever rests against the edge of the material. The opposite end of the lever is connected to a differential transformer. Any variation in the width of the material moves the lever and repositions the core of the transformer. The amount of core displacement and consequent current flow can be calibrated to the variation in material width.

Width of hot-metal strip in rolling mills can be measured and recorded by means of a photoelectric transducer, Fig. 62. As the hot strip passes under a scanner, infrared radiation from the hot strip is reflected to an infrared-sensing cell. The scanner contains a rotating prism which brings successive faces sweeping across the area of view of the gage hundreds of times per second. This scanning action reflects no radiation to the sensing cell until a face has rotated to a position where it "sees" the first hot-strip edge. The scanner continues to reflect this heat as it traverses that portion of the

field of view occupied by the strip. Radiation stops when the prism face has rotated to the point where its field of view leaves the opposite edge of the hot strip.

The sensed radiation is shown as wave-form A in Fig. 62. The width of signal A represents the strip width; the amplitude is a function of the temperature. Wave-form B is the result of differentiating circuits applied to the original signal and indicates the point of maximum rate of change of the scanning signal. Signal B is used to trigger a multi-vibrator which provides a square-wave output, signal C. The signal obtained by averaging the energy contained in these square waves, which have a fixed amplitude and are projected on a time axis, is independent of strip temperature. Signal C is determined only by the width of the hot strip. As shown, C plus X indicates an increase in width of strip. A calibrated dial, set at zero for nominal width, can be used for direct indication of strip width.

Basic Electronic Controls—2

In the December 7 issue of MACHINE DESIGN, an article on electronic controls will discuss indicators, recorders, and controllers. Indicators and recorders give evidence of variations in process control so that corrections or improvements can be made at the proper times and places. Controllers are the devices which measure the deviation from normal and provide the control signal to an actuator.

A designer's guide to THERMAL STRESSES

Part 2—Comparative Suitability of Materials

S. S. MANSON

Chief, Materials and Structures Research Div.
Lewis Research Center, NASA
Cleveland, Ohio

ALTHOUGH the suitability of a material for a given application can be evaluated by analyzing the expected stresses and strains, it is frequently helpful to determine the relative merits of various materials under service conditions.

Parameters have already been developed for rating brittle materials under thermal shock.¹ Such parameters can also be developed for rating brittle materials under static thermal-stress conditions; still another set of rating parameters can be found for ductile materials.

Brittle Materials

Two basic parameters—depending on the application—can be used in rating brittle materials under static thermal-stress conditions. In one case, the temperature gradient is specified, while in the other, heat flow is specified. Both of these parameters correspond to those developed for rating brittle materials under thermal shock.

Specified Temperature Gradient: In many practical applications, regardless of the material chosen, temperature differentials remain constant. A typical case is a long tube carrying a hot liquid and cooled on the outside. Temperature of the inside surface is governed by the temperature of the liquid, while that

¹References are tabulated at end of article.

Nomenclature

A	= Inner radius of cylinder
a	= Plate half-thickness
B	= Outer radius of cylinder
D	= Ductility
E	= Elastic modulus
G	= Material constant determined by test
h	= Heat-transfer coefficient
k	= Conductivity
M	= Material constant determined by test
N	= Cycles to failure
N_e	= Cyclic life for determining endurance limit
N_f	= Cycles to fracture
Q	= Quantity of heat
ΔT	= Temperature differential
T_o	= Initial uniform temperature of plate test specimen
Z	= Material constant determined by test
α	= Coefficient of expansion
β	= Biot's modulus or nondimensional heat-transfer parameter
γ	= Material constant determined by test
$\Delta \epsilon_{el}$	= Elastic-strain component in total-strain equation
ϵ_{max}	= Maximum elastic strain
ϵ_p	= Plastic strain
$\Delta \epsilon$	= Total strain
μ	= Poisson's ratio
σ	= Allowable stress
$\Delta \sigma$	= Stress range
σ_{end}	= Endurance limit
σ_f	= True stress at fracture
σ_{max}	= Maximum stress

of the inner surface is governed by the coolant.

For this type of application the best material is the one capable of withstanding the highest temperature differential ΔT between the liquid and the coolant. Then, from the applicable stress formula,³

$$\frac{\sigma(1-\mu)}{E\alpha} = \frac{\Delta T}{2} \frac{\left(1 - \frac{2A^2}{B^2 - A^2} \ln \frac{B}{A}\right)}{\ln \frac{B}{A}} \quad (1)$$

where B and A are the outer and inner radii of the cylinder.

This equation shows that the material having the highest value of $\sigma(1-\mu)/E\alpha$ can withstand the largest ΔT . In practical applications, the approximate equivalent $\sigma/E\alpha$ may be used, since Poisson's ratio does not vary greatly among materials.

Specified Heat Flow: In some applications the amount of heat that is to be transferred across the tube is specified. A typical example is a ceramic tube surrounding a heating element. The heat generated in the element is specified for a given application, and the surrounding tube must be capable of conducting this heat without fracturing.

The temperature differential across the ceramic tube depends on material conductivity k , and on heat quantity Q , that must be conducted per unit length of tube. Thus,

$$\Delta T = \frac{Q \ln \frac{B}{A}}{2\pi k}$$

Substituting into Equation 1:

$$\frac{k\sigma(1-\mu)}{E\alpha} = \frac{Q}{4\pi} \left(1 - \frac{2A^2}{B^2 - A^2} \ln \frac{B}{A}\right) \quad (2)$$

In this case, since B and A are specified, the material with the highest value of $k\sigma(1-\mu)/E\alpha$ can withstand the highest value of Q .

Typical Materials: Since the rating parameters are different, relative performance of the materials depends on the application. Experimental comparisons have been made—using ceramics—to test the validity of the equations for elastic stress in a hollow cylinder as a criterion for predicting failure. Since physical properties of ceramics vary widely as temperature increases, the variation of all the pertinent physical properties over a wide range of temperatures was measured. The stress elastically computed from these properties was compared with the experimental strength at each temperature, Fig. 6. Thermal stresses were generated by a Globar heating element located at the center of the hollow cylinder.

Other Configurations: The basic parameters $\sigma(1-\mu)/E\alpha$ and $k\sigma(1-\mu)/E\alpha$ are not restricted to circular cylinders. Other configurations can readily be analyzed by conventional techniques of elasticity.

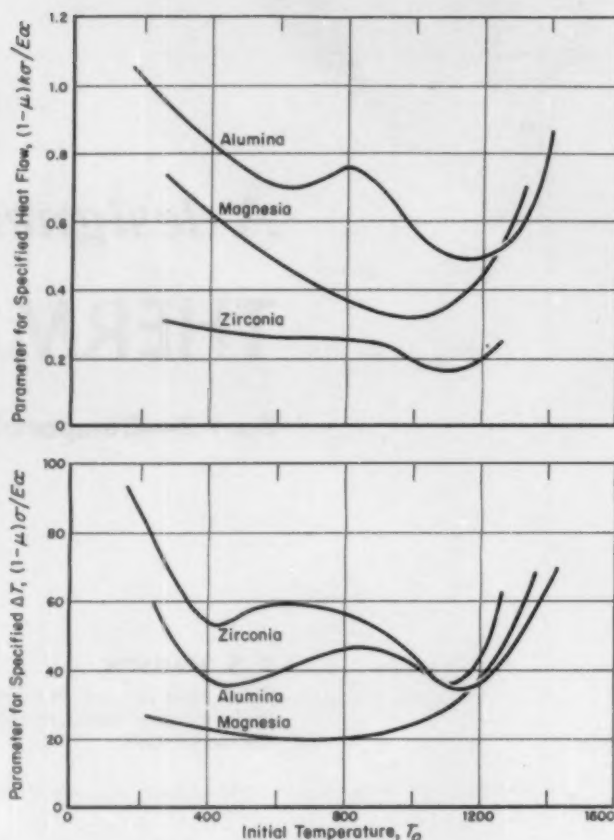


Fig. 6—Comparison of thermal-stress characteristics for three different materials. As shown, the order of superiority changes with a change in rating parameter.

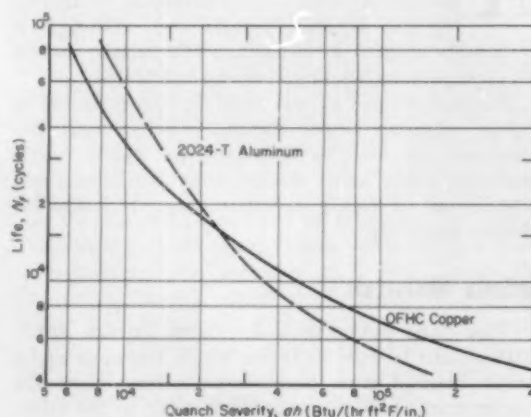


Fig. 7—Comparison of OFHC copper and 2024-T aluminum in thermal shock. In this test, $\Delta T = 750$ F.

The parameters are the same, but the manner in which they are used in the various functions is somewhat different for each case.

Ductile Materials

With ductile materials, the mechanisms of distortion and fatigue, rather than fracture caused by a single cycle, must be considered. This article considers fatigue only, since the mechanism of progressive distortion is as yet only poorly analyzed.

Thermal-stress fatigue under slow temperature cycling is a complex phenomenon involving mechanical and metallurgical considerations. When the effects of thermal shock are introduced, the problem becomes even more complicated. Often-times, the relative resistance to thermal shock of ductile materials seems to follow no logical pattern. An understanding of the many variables involved will, however, serve as a basis for understanding some of the complexities involved.

Total Strain: The general relationship between total strain and cyclic life is

$$\Delta \epsilon = M N_f^\beta + \frac{G}{E} N_f^\gamma \quad (3)$$

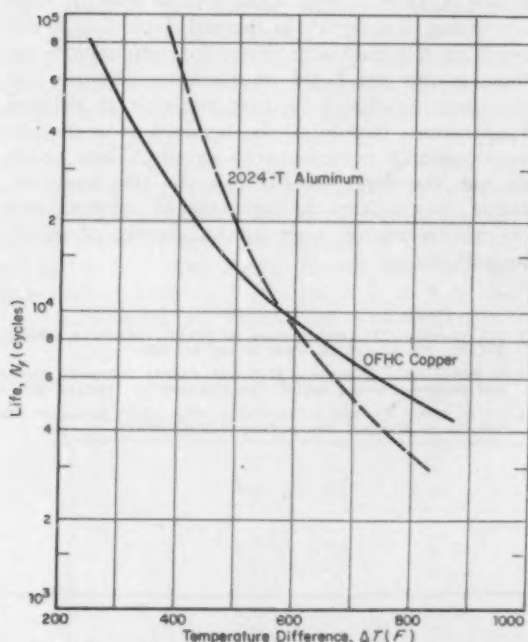


Fig. 8—A comparison of OFHC Cu and 2024-T Al in thermal shock, with quench severity $ah = 10^5$ Btu/(hr ft² F/in.). This figure, along with Fig. 2, is not intended to rate the two materials, but rather to indicate the effect of test conditions on relative ratings.

In general, therefore, four material constants— M , Z , G , and γ —govern cyclic life. These material constants are not usually familiar to the designer. However, they can be expressed in more familiar terms, that can be grouped into useful thermal-shock parameters.

The following simplifying assumptions can be made:

1. The plot for plastic strain versus cyclic life on log-log co-ordinates is a straight line of slope $= -1/2$, and passes through the point $\epsilon_p = 1.5D$ at $N = 1/4$.

2. The line for elastic strain versus cyclic life, plotted on log-log co-ordinates, is also straight. One point on this line corresponds to $\Delta \sigma = 2\sigma_f$ at $N_f = 1/4$, where σ_f is the true stress at fracture. The other point is at the endurance limit, where the stress range is $\Delta \sigma = 2\sigma_{end}$ and the cyclic life is N_e , usually chosen as 10^6 cycles.

Thus, total strain is

$$\Delta \epsilon = \epsilon_p + \epsilon_{el} = \frac{0.75D}{N_f^{1/2}} + \frac{2\sigma_f}{E} \left[\left(\frac{1}{4N_f^{1/2}} \right) \frac{\log \sigma_f/\sigma_{end}}{\log 4N_e} \right] \quad (4)$$

where $\Delta \epsilon_{el}$ is the elastic-strain component.

Either Equation 3 or 4 can be used in deriving thermal-shock parameters.

Strain in Thermal Shock: Since an approximate equation is adequate to identify the important material parameters, the simplest approach is to assume that the elastic stress is equal to the true total strain. Taking as an example a flat plate, maximum elastic strain can be obtained by dividing maximum stress by the elastic modulus. Thus,

$$\epsilon_{max} = \frac{\sigma_{max}}{E} = \frac{\alpha T_o}{1 - \mu} \left[\frac{1}{1.5 + (3.25k/ah) - 0.5e^{-16k/ah}} \right] \quad (5)$$

Then, from Equations 4 and 5,

$$\frac{D(1 - \mu)/\alpha}{N_f^{1/2}} + \frac{2\sigma_f(1 - \mu)}{E\alpha} \left(\frac{1}{4N_f^{1/2}} \right) \frac{\log \sigma_f/\sigma_{end}}{\log 4N_e} = T_o \left[\frac{1}{1.5 + (3.25k/ah) - 0.5e^{-16k/ah}} \right] \quad (6)$$

or using Equation 3 instead of 4,

$$\frac{M(1 - \mu)}{\alpha} N_f^\beta + \frac{G(1 - \mu)}{E\alpha} N_f^\gamma = T_o \left[\frac{1}{1.5 + (3.25k/ah) - 0.5e^{-16k/ah}} \right] \quad (7)$$

Thermal Shock Parameters: From Equation 7 the parameters that govern cyclic life to fracture N_f are

$$\frac{M(1 - \mu)}{\alpha}, Z, \frac{G(1 - \mu)}{E}, \gamma, k$$

The term ah is, of course, not dependent on material

properties, but on quench severity.

Since these basic material parameters involve properties M , G , γ , and Z not normally familiar to the designer, it is preferable to refer to Equation 6 to obtain approximations in more familiar terms:

$$\frac{D(1-\mu)}{\alpha}, \frac{\sigma_f(1-\mu)}{E\alpha}, \frac{\log \sigma_f/\sigma_{end}}{\log 4N_s}, k$$

Since in this case the slope of the ϵ_p vs N_f curve has been taken as $-1/2$ for all materials, only four parameters are needed.

Resistance of Materials: The relative resistance of a number of materials to a given type of thermal shock depends on the conditions causing the shock. In mild shocks (low β) for example, since temperature distribution is governed to a considerable extent by the conductivity of the material, the good conductors have a relative advantage over the poor conductors. For severe thermal shock (high β) the induced strain is governed largely by the term ΔT , and is almost independent of the material conductivity; hence, the materials with the highest value of D/α , or $D(1-\mu)/\alpha$ will be best, regardless of their conductivity.

When ΔT is large, and thus plastic strain is high, ductility will very likely govern cyclic life, and the materials of highest ductility will tend to have the highest cyclic life. When ΔT is small, the strain may be governed largely by elastic characteristics, and the material with the highest endurance limit will be best.

Thus shock conditions must be specified in rating ductile materials, since their relative merit may change, depending on conditions. In addition, it is important to consider the changing metallurgy of the materials as temperatures increase. Properties of some materials deteriorate rapidly as the temperature is raised.

In a thermal-shock test the tensile-plastic (or nominally elastic) strains are induced at one temperature while the compressive strains may be induced at a different temperature. For this reason,

Table 1—Rating Parameters for Ductile Materials

Parameter	Units	Material	
		OFHC Copper	2024-T Aluminum
$M(1-\mu)/\alpha$	deg F	99.4×10^3	38.7×10^3
Z	-0.636	-0.593
$G(1-\mu)/E\alpha$	deg F	840	820
γ	-0.146	-0.0756
k	Btu/(hr ft ² F/in.)	2700	1100

it is always desirable to perform at least some thermal cycling tests involving strains at anticipated temperatures, before attempting to predict the relative performance of various materials for a given application.

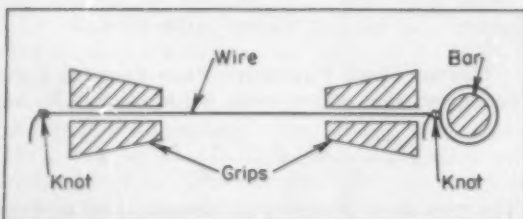
Example: A comparison of OFHC copper and 2024-T aluminum illustrates how relative ratings of materials change with changes in test conditions. The strain-cycling properties of these two materials are known² for room temperatures. Based on these strain-cycling properties, and other readily available physical properties, the thermal-shock parameters are as shown in Table 1. Figs. 7 and 8 show how the relative rating of materials in thermal-shock fatigue depends on test conditions. Since the computations for these graphs are based on room temperature, the changing metallurgy of these materials at elevated temperatures that might be involved in such tests are necessarily not taken into account. These charts do not, therefore, actually rate the two materials; rather, they indicate the importance of test conditions on relative ratings even in the absence of metallurgical change.

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Tips and Techniques

Testing Wires



It is often extremely difficult to clamp thin wires, electrical cables, and ropes between the grips of a tensile machine. A useful method is to tie a knot behind each set of grips, as shown. Brittle wires should be wrapped around a bar before the knot is tied.—KARL M. WEIGERT, *Pennsylvania State University, University Park, Pa.*

Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables, or photos to: Tips and Techniques Editor, MACHINE DESIGN, Fenton Bldg., Cleveland 13, O.

Need a simple, low-cost beam? Try

Sheet-Metal Channels

Here are tables for picking the best section proportions

JEROME MENDEL

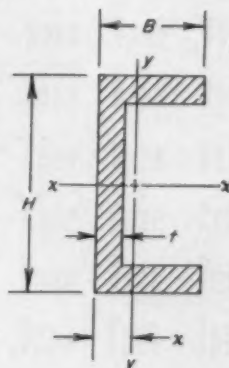
Senior Mechanical Engineer
Lockheed Electronics Co.
Plainfield, N. J.

SMALL channels bent from sheet metal can be tailored to any section proportions within the limits of available forming equipment. As a result, wide latitude is offered in the design of beams with specific section properties which can not be obtained with conventional structural shapes.

Tables for quick selection of the best section proportions for a sheet-metal channel are presented on the following page (symbols are defined in Nomenclature). These tables give areas, section moduli, and centroidal distances for channels of 1/32, 1/16, and 1/8-in. thick sheet metal. Flange-web combinations varying from 1/4 x 1/2 in. to 2 x 3 in., in 1/4-in. increments, are covered for each thickness.

Fractional thicknesses, which correspond roughly to 22 (1/32 in.), 16 (1/16 in.), and 11 (1/8 in.) gage sheets, are used here for ease of layout. For intermediate thicknesses, section properties can be approximated by interpolating. For example, a channel of 0.040-in. thick sheet metal will have properties that fall about midway between those for 1/32 and 1/16-in. sheet.

Keep in mind that each increment of flange depth alters the section area, and material, by twice the amount for an equal change in the web dimension. It also produces a maximum change in the value of Y . For maximum increase or decrease in X , the web dimension should be altered.



Nomenclature

- A = Section area, sq in.
- B = Width of section (flange), in.
- H = Depth of section (web), in.
- t = Metal thickness, in.
- X = Section modulus about x -axis, in.³
- x = Centroidal distance (base of web to centroid), in.
- Y = Section modulus about y -axis, in.³

$t = 1/8$ in. (0.125 in.)

[illegible]



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Performance ratings and application factors for

Universal Joints

W. T. CONDON

Project Engineer
Twin Disc Clutch Co.
Racine, Wis.

FOR proper application of a universal joint, two pertinent facts about the joint must be known: Its static torsional capacity, and its dynamic bearing capacity.

Sufficient information and data on the joint must be available to permit design of a properly proportioned driveline which will minimize the problems resulting from nonuniform displacement, velocity, and acceleration produced by a Cardan or Hooke's type joint, and will avoid operating the shaft near its natural bending frequency.

Operating conditions must also be known. They include torques, speeds, angles, and environmental conditions.

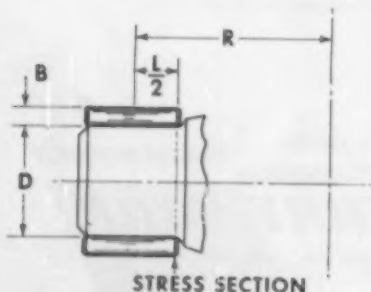


Fig. 1—Cross-trunnion assembly.

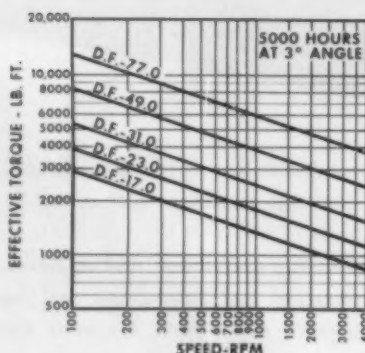


Fig. 2—Universal-joint life curves for selected dynamic factors (D.F.).

Universal Joint Ratings: A typical universal joint and propeller-shaft assembly is composed of two cross-and-bearing assemblies, and a connecting shaft which may either be tubing or solid shafting. The cross and bearing assembly consists of four inner bearing races on the cross, four needle-bearing assemblies, and four outer-race caps.

For this universal joint, two ratings are required. One defines the physical strength of the assembly in torsion without regard to speed or angle. The second defines the

needle bearing dynamic capacity.

It is possible to obtain a uniform method of rating both static and dynamic properties of a particular design by investigation of the physical dimensions of the cross and the needle-bearing geometry.

The cross trunnion or inner race of the needle bearing is the critical strength component. Therefore, only the stress level of the cross need be defined. The trunnion is loaded as a cantilever beam; therefore, the trunnion is subjected to bending and shear loading, Fig. 1.

The principal stress in the trunnion is:

$$S_1 = \frac{S_t}{2} \pm \sqrt{S_t^2 + S_s^2} \quad (1)$$

where

$$S_t = \frac{PL}{0.196 D^3} = \frac{5.1 PL}{D^3}$$

$$S_s = \frac{PL}{0.7854 D^2} = \frac{1.27 P}{D^2}$$

$$S_1 = \frac{2.55 PL}{D^3} \pm \sqrt{\frac{6.5 P^2 L^2}{D^6} + \frac{1.6 P^2}{D^4}}$$

SIX PUSHBUTTON SWITCHES

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CONTROL SWITCH DIVISION

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W100 is available at S.P.S.T. (N.O. or N.C.), S.P.D.T., 2-circuit, and 3-terminal (N.O. or N.C.). Designed to MIL-S-6743, MS-25089. Completely moisture-proof and enclosed in anodized aluminum case with silicon rubber boot. Available with any of 8 mounting adapters (Adapter P shown) to meet any mounting or panel requirement. Rated 10 amps at 28 VDC resistive.

LOW COST, U.L. LISTED

B2000 series switches are considerably smaller than standard $\frac{1}{2}$ amp momentary pushbuttons, yet cost much less and actually are U.L. rated at 8 amps, 120 VAC. Select S.P.S.T. circuit either N.O. or N.C., with solder lugs or pigtail leads. Mounts in $\frac{1}{2}$ " dia. hole.

WITH OR WITHOUT LIGHT

WC1500 is a very small moisture-proof switch (designed to MIL-S-6743) with a minimum life of 25,000 operations at rated load. Available with or without indicator light in pushbutton, and rated at 2 amp ind. or 4 amp res., 28 VDC. D.P.D.T. or 4-circuit. Mounts in $\frac{3}{8}$ " diameter panel hole.

MOISTURE-PROOF, ALTERNATE ACTION

J3136 is a new moisture-proof switch originally designed for military ground support and aircraft equipment. Two-circuits, rated at 5 amp ind. or 10 amps res. at 28 VDC; 5 amp (.75 P.F.) ind. or 10 amp res. at 120 VAC. Life is 25,000 operations min. at rated load. Anodized aluminum case with solder lug terminals, and 8 styles of mounting adapters available. Mounts in $\frac{3}{8}$ " dia. hole.

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J100 is a S.P.S.T. switch rated 20 amps res. at 28 VDC; 10 amps res. at 115 VAC. Ruggedly built to give compactness and durability under critical operating conditions. Weighs only 1 oz. Total plunger travel is only $\frac{1}{4}$ ". Overall size: 1" diameter, $2\frac{1}{4}$ " long.



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For any given cross and bearing, Equation 1 can be solved for the load, P (lb), which will produce 10 psi stress. When this value is modified by the distance R , the expression PR is an index of the static torque capacity and can be referred to as the static factor, S.F.:

$$\text{S.F.} = \frac{10RD^3}{2.55L + \sqrt{L^2 + 0.25D^2}} \quad (2)$$

Because most universal joint cross designs are similar, the static factor can be used to compare strengths of all universal joint sizes.

The dynamic bearing capacity, C , of a needle bearing is the load in pounds which can be sustained for 1×10^6 revolutions by 90 per cent

of a large group of bearings. Thus,

$$C = F \times N^{2/3} \times L \times B \quad (3)$$

where coefficient F is dependent upon material, degree of oscillation, uneven load distribution, and accuracy of manufacture; N = number of needles; L = effective length of the needle; B = needle diameter.

Although the contact stresses are higher and the static Brinell capacity of a caged needle bearing exceeds that of a full complement needle design. Another important factor is that the caged needle bearing can use relieved-end needles to full advantage. It can also be shown from capacity equations that dynamic capacity increases with increasing needle diameter.

For any given needle-bearing geometry, the load, C (lb), which results in a B10 life of 1×10^6 revolutions can be determined. The dynamic capacity of the needle bearing is modified by the distance R , and then divided by 10^3 to obtain a conveniently small number which can be referred to as the dynamic factor, D.F.:

$$\text{D.F.} = \frac{CR}{10^3} \quad (4)$$

A static factor and dynamic factor are useful for comparing relative capacities of competitive universal joints. However, to be fully meaningful, a static factor must be developed which uses the dynamic factor to predict the life of an oscillating universal joint needle bearing at various torques, speeds, and angles.

The traditional safety factor for shock loading is two, although it

can be much higher. Therefore, a reasonable rated torque would be 45 per cent of the universal-joint yield torque. This rating is applicable to only the physical torque-carrying capacity of the assembly and is not related to the needle-bearing capacity.

Life L (hr) in terms of speed n (rpm), load P , and dynamic bearing capacity C , is

$$L = \frac{16666}{n} \times \frac{C^3}{P} \quad (5)$$

Equation 5 must now be modified for universal joint oscillation, and further modified so that the torque and the dynamic factor can be inserted. Thus,

$$L = \frac{6.95 \times 10^3}{n\theta} \left(\frac{\text{D.F.} \times 10^3}{\text{Torque}} \right)^3 \quad (6)$$

On the basis of the life expression, Equation 6, Fig. 2 can be constructed. It indicates the universal-joint size required for 5000 hr of B10 bearing life at 3-deg angle. If life other than 5000 hr is required, the torque must be modified by a life factor shown in Fig. 3. If angles other than 3-deg are used, the torque must be modified by an angle factor shown in Fig. 4. Note that the angle-factor curve starts at 3 deg which is considered as the base point for joint angularity. Further modification of torque may be required depending upon the position of the universal joint in a power train and the application. The torque value used for universal-joint size selection is

$$T_E = T \times K_1 \times K_2 \times K_3$$

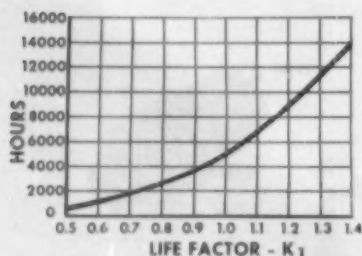


Fig. 3—Factor for life more than 5000 hr.

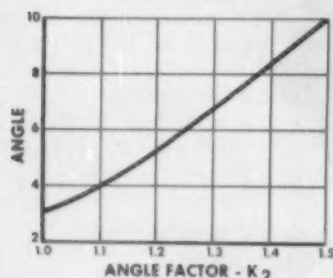


Fig. 4—Factor for shaft angles greater than 3 deg.

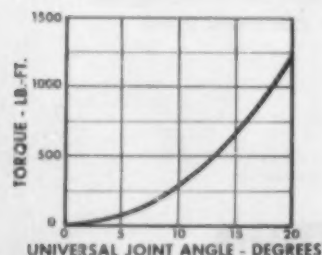


Fig. 5—Maximum acceleration torque as a function of universal-joint angle.

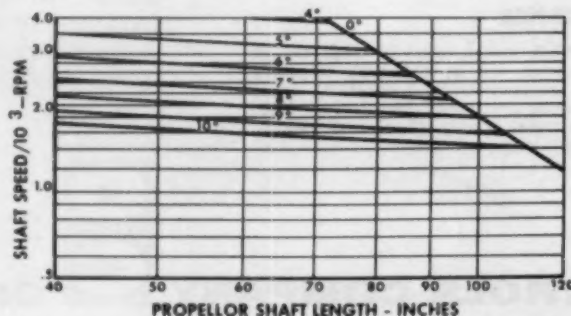


Fig. 6—Limiting speed and angle relationship.



Molysulfide® News Digest

CLIMAX MOLYBDENUM COMPANY, a division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N.Y.

EDITORIAL PAGES OF LEADING TRADE MAGAZINES FEATURE MoS₂ INFORMATION

Higher temperatures, lower temperatures, greater pressures, longer lubrication life, all have combined to focus more attention on the uncommon lubricating values of molybdenum disulphide.

That's why editors are devoting more and more space to descriptions of what MoS₂ can and cannot do.

One article tells how MoS₂ pre-

vents harmful friction in brake linings. Another discusses its use as a compressor lube substitute. Still another reports on tests of epoxy-resin compositions containing high concentrations of MoS₂ for industrial use on bearings, seals and friction strips.

Press fittings, wire drawing, cutting tools, ball joints—there are MoS₂ stories about these uses, too.

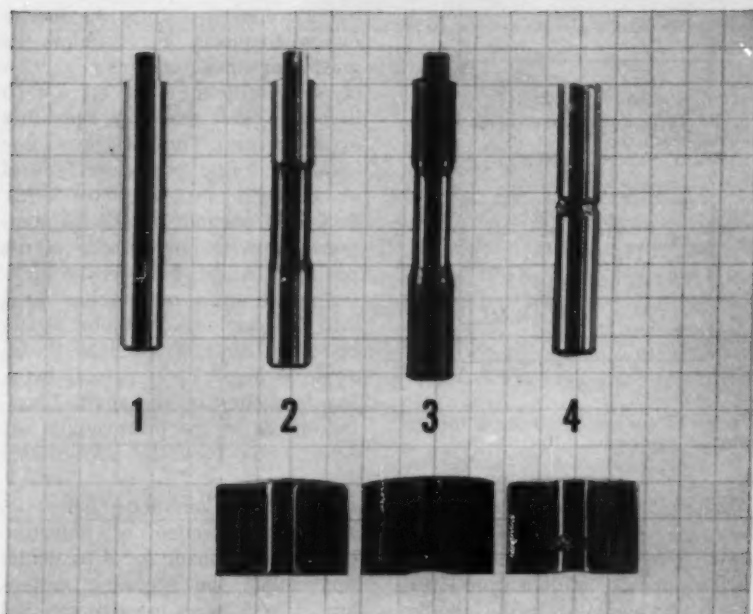
MoS₂ as a solid-film dry lubricant has been the subject of several articles. One details high-temperature properties; another describes a new bearing design that can increase bearing life as much as 450%.

Write us for a complete bibliography of published material on molybdenum disulphide.

P.S. Climax publishes a newsletter that describes even more uses. Let us know if you'd like your name on the mailing list.

Circle 282 on Page 19

Proof of MoS₂'s High-Pressure Properties



Photograph above shows mild steel test pins. No. 1: Unused pin, No. 2 (lubricated with mineral oil and Molysulfide) and No. 3 (with Moly-sulfide bonded coating) were subjected to rotating pressures between bearing halves. Both were elongated

and extruded without galling, seizing, or weight loss. No. 4 shows typical failure with conventional lubricant. Note that the key sheared off and pin and block were galled and seized.

Circle 283 on Page 19

ASME SHOW DEVOTES SESSION TO "MOLY" LUBES

New evidence of mounting interest in molybdenum disulphide was shown recently among members of the American Society of Mechanical Engineers. A spokesman for the Climax Chemical Division was invited to speak on "Molybdenum Disulphide as a Lubricant" before the Machine Design Division at the 1961 Design Engineering Conference. A copy of this 24-page paper is available on request.

At the same meeting, engineers from Socony Mobil Oil Company spoke on "Molybdenum Disulphide as an Additive to Improve the Performance of an Automotive Multi-purpose Grease." Write to Climax for a copy of this paper.

Circle 284 on Page 19



5 STEPS ELIMINATED

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DESIGN ABSTRACTS

where K_1 = life factor, K_2 = angle factor, and K_3 = application factor.

For example, consider a simple power train in which: Universal joint torque = 2000 lb-ft, shaft speed = 800 rpm, universal joint angle = 3 deg, desired life = 5000 hr, $K_1 = 1.00$, $K_2 = 1.0$, and $K_3 = 1.0$. Then $T_B = 2000(1)(1)(1) = 2000$ lb-ft.

From Fig. 2, the intersection of the 2000 lb-ft torque and the 8000 rpm lines indicates that a 23.0 dynamic factor would meet the requirement.

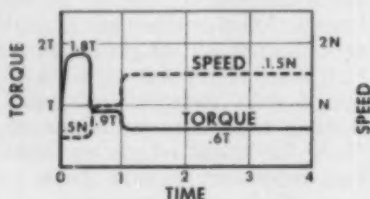


Fig. 7—Torque-speed-time curves for a highway vehicle.

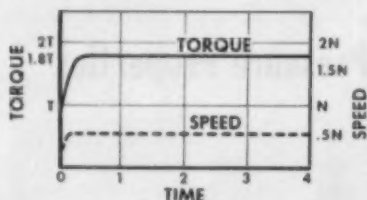


Fig. 8—Torque-speed-time curves for industrial machinery.

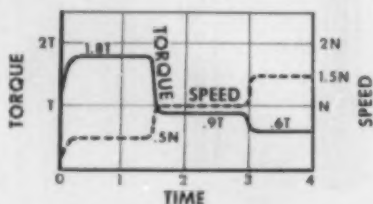


Fig. 9—Torque-speed-time curves for construction equipment.

When the operating conditions vary, the expected life of the universal joint must be calculated for each group of conditions from Equation 6, and combined in the cumulative-damage equation,

$$\text{Life} = \frac{1}{\frac{N_1}{L_1} \frac{N_2}{L_2} \frac{N_3}{L_3} \dots \frac{N_n}{L_n}} \quad (7)$$

where L_1 = Life at condition 1, and

N_1 = Fraction of time at condition 1.

The B10 life of the individual needle bearings in a universal joint can be calculated using Equation 6.

In a large group of cross-and-bearing assemblies, the probability is that 65 per cent of the assemblies will reach or exceed the predicted B10 life of the individual bearings.

Driveline Configuration: It has been shown that large operating angles require larger dynamic-factor universal joints from the life aspect. However, successful universal-joint applications require that continuous operating angles remain small—on the order of 2-5 deg—although angles up to 20 deg are permissible for short duration operation.

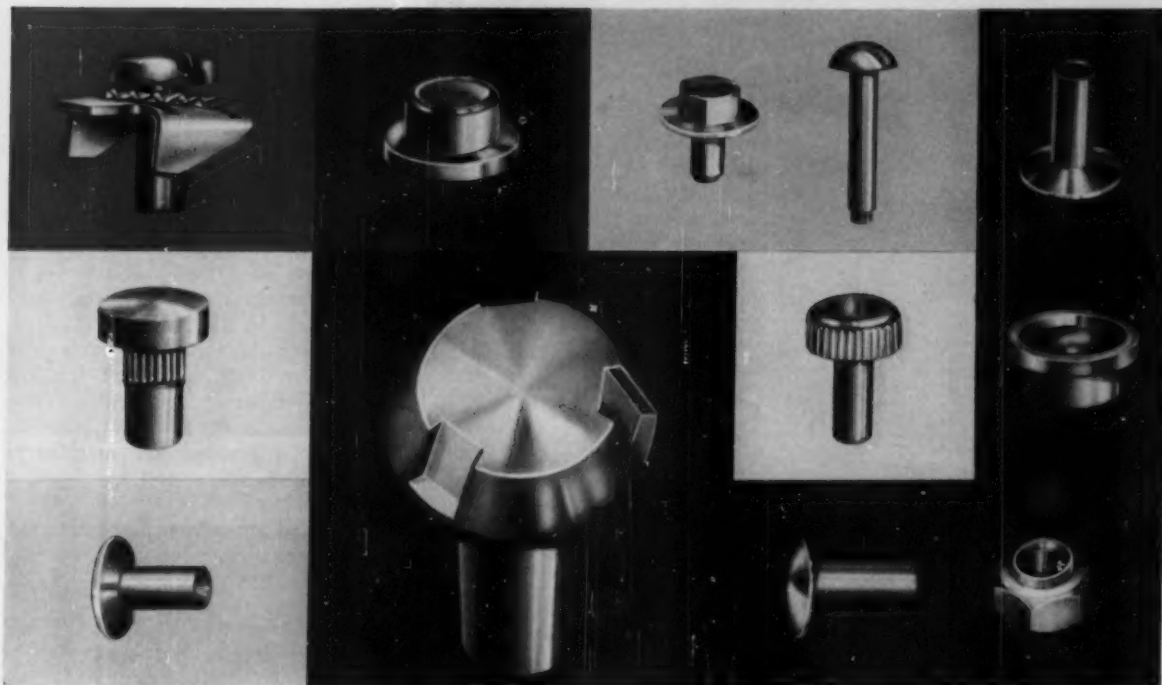
Heavy-duty universal-joints used in construction and industrial machinery have limiting angles which are a function of a speed and mass moment of inertia of the universal-joint shaft assembly. Limiting angles are required because of the effect of the angular acceleration of the center shaft of the universal-joint shaft assembly. The acceleration and deceleration of the center mass requires a cyclic torque input, with a frequency of two times the fundamental frequency. Fig. 5 shows the maximum input torque as a function of universal-joint angle for a 0.10 lb-ft-sec² shaft assembly operating at 3000 rpm. These cyclic torque loads can cause premature failures of universal-joints, excessive vibration, and possible failures of components on the driver side of the power train. Fig. 6 shows the limiting speed angle relationship for a 0.10 lb-ft-sec² universal-joint assembly. The limiting speed at 0 deg angle is based upon natural bending frequency of the shaft. Limiting speeds at the other angles are based upon successful applications.

Operating Conditions: Before an intelligent selection of universal-joints can be made for a particular application, the operating torques, angles, and speeds must be specified for calculation of life expectancy of the joint.

The danger in applying universal-joints on the basis of maximum torque alone, and the importance of a duty cycle are illustrated by three torque-speed-time curves of typical

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Photo courtesy Cushman Motors

R/M found friction material answers for versatile Cushman Trailster

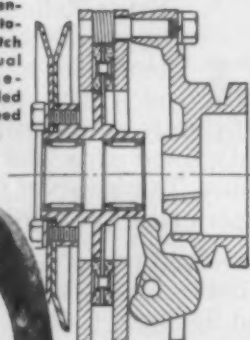
"We placed our friction problems for the Trailster's centrifugal automatic clutch in Raybestos-Manhattan's hands," says R. D. Von Seggern, assistant chief engineer, Cushman Motors, Lincoln, Nebr.

"Cushman has been using Raybestos-Manhattan friction materials in various models of utility vehicles for over 15 years. Based on past experience, we know we can rely on them for assistance at every stage—from design to production.

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DESIGN ABSTRACTS

applications, Fig. 7, 8, 9. These conditions represent those which the universal-joint propeller shaft will see and are based upon constant and identical universal-joint angles.

All three applications have the same maximum torque and on the basis of this they could all use the same universal-joint size. However, from the life aspect, it is obvious that the same universal-joint size would not be correct for all three. To determine the proper universal-joint size for each application, it is necessary to construct a duty cycle for each and apply the cumulative-damage theory as in Equation 7.

To obtain life equal to the highway vehicle, the industrial machinery and construction equipment universal-joints must have the following dynamic factors: For industrial machinery, dynamic factor = 1.61; for construction machinery, dynamic factor = 1.51.

Design Procedure: Steps required in selection of the proper universal-joint size are:

1. Calculate maximum torque transmitted.
2. Make tentative joint size selection based on rated torque of universal-joints available.
3. Tabulate duty cycle using application factors if required.
4. Calculate life expectancy of tentative joint selection.
5. If size is adequate with respect to life, determine maximum speed and check limiting speed-angle relationship.
6. Check schematic of driveline to determine if phasing is required.

SAE Paper No. 403B, "Application of Universal Joints to Construction and Industrial Machinery," presented at the Heavy-Duty Vehicle Meeting, Milwaukee, September, 1961, 10 pp.

bearings

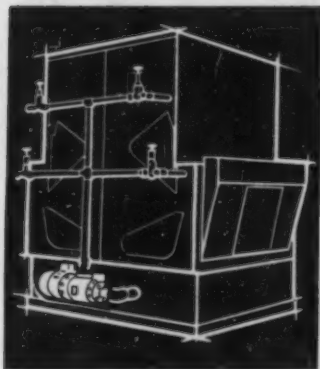
Sleeve Bearings and Plain Thrust Washers in Automatic Transmissions

William A. Weinkamer, Cleveland Graphite Bronze Div. of Clevite Corp.

A study of ten current-production passenger-car automatic transmis-

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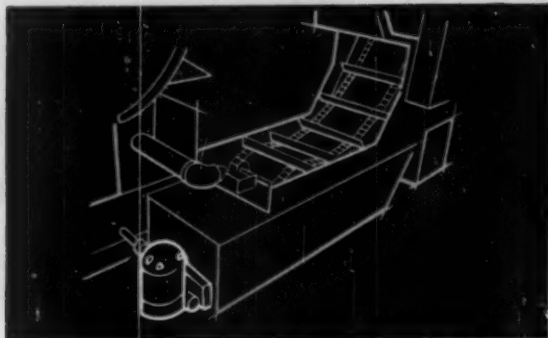
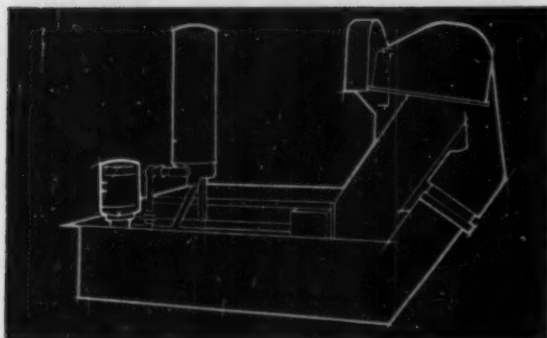
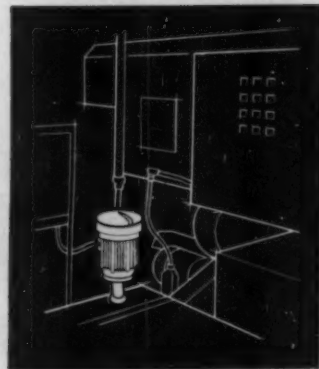
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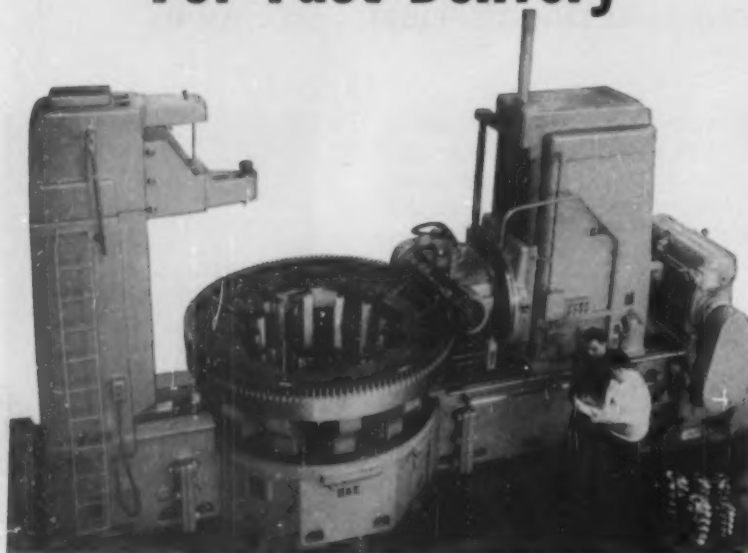
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sions made through the co-operation of the participating members of the SAE Transmission Subcommittee D.

A total of 85 bushing and 66 thrust washer applications were found in these models. In each instance, the complete environment was investigated to determine the bearing or washer material, the journal or thrust runner material and finishes, loads and speeds, and finally the groove design used to promote load-carrying capacity and cooling of the bearing surface.

SAE Paper No. 359E, "Design of Sleeve Bearings and Plain Thrust Washers in Current Passenger Car Automatic Transmissions," presented at the 1961 Summer Meeting, St. Louis, June 1961, 19 pp.

Optimum Stiffness of Pressurized Bearings

Marvin T. S. Long, senior research engineer, Physical Research Dept., Cincinnati Milling Machine Co., Cincinnati, Ohio

Theoretical studies of the method of optimization of the stiffness of externally pressurized bearings.

When an externally pressurized bearing is designed to operate at any given film thickness, it is found that the maximum bearing stiffness can be obtained by proper selection of the value of the ratio of recess to supply pressure, P_r/P_s . While various values of P_r/P_s can be attained by either varying the restrictor constant for a given film thickness or varying the film thickness for a given restrictor constant, the important quantity to vary in determining the optimum condition is the restrictor constant rather than the film thickness.

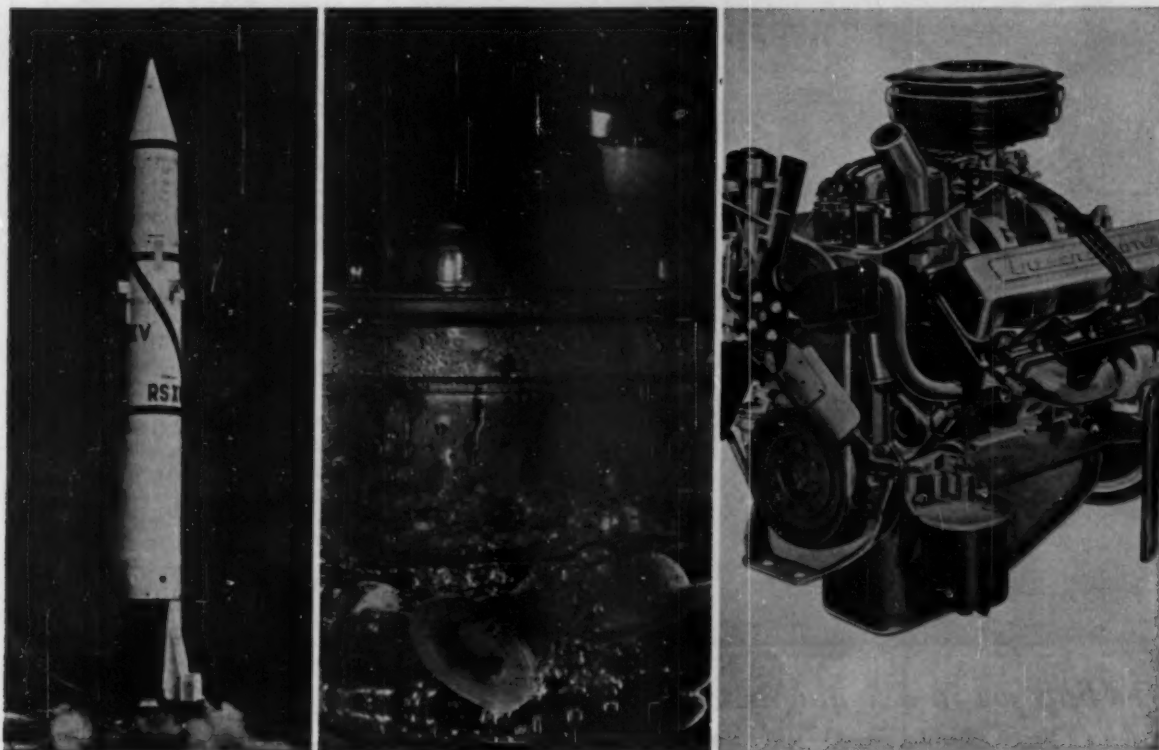
For an incompressible fluid, the P_r/P_s value for which the bearing stiffness is optimized depends only on the type of compensation used, while for a compressible fluid it is slightly affected by exhaust pressure.

ASME Paper No. 61-LUB-3, "On the Optimization of the Stiffness of Externally Pressurized Bearings," presented at the ASLE-ASME Lubrication Conference, Chicago, Oct., 1961, 4 pp.

Ceramic Rolling-Contact Bearing for High Temperatures

K. M. Taylor, Research and Development Div., Carborundum Co., Niagara Falls, N. Y.; L. B. Sibley, Battelle Memorial Institute, Columbus, Ohio,

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DESIGN ABSTRACTS

and J. C. Lawrence, SKF Industries Inc., Philadelphia, Pa.

Development of a ceramic ball bearing for use at temperatures of about 1000 to 1500 F.

Several selected combinations of ceramic and cermet materials were screened in simple sliding and rolling experiments, and the most promising materials were selected for fabrication into full-scale bearings.

Sliding friction and wear tests and four-ball wear tests show that when lubricants are not used, the performance of K163B1 titanium-carbide cermet operating against itself or against hot-pressed alumina or hot-pressed silicon carbide is superior to other possible two-component combinations of these three materials.

Bearing experiments at temperatures of 1000 and 1500 F demonstrated the feasibility of bearing operation at these temperatures with little or no wear under moderate load and speed.

ASME Paper No. 61-LUB-12, "Development of a Ceramic Rolling Contact Bearing for High Temperature Use," presented at the ASME-ASLE Lubrication Conference, Chicago, October, 1961, 11 pp.

Externally-Pressurized Air-Lubricated Journal Bearings

Jason R. Lemon, research consultant, Cincinnati Milling Machine Co., Cincinnati, Ohio

Simplified analysis for calculating the characteristics, such as stiffness, flow, and load, of an externally-pressurized gas journal bearing.

A standard one-dimensional flow approach is altered to take into account the effect of circumferential pressure variations.

From this analysis, it is revealed that bearing stiffness has an optimum which, it is further shown, can be chosen through a proper selection of bearing design parameters, such as radial clearance, upstream resistor, and supply pressure.

As the analysis is developed each assumption is experimentally verified. The final predictions of the analysis are also verified.

It is felt that the analysis is sufficiently simple to allow comparison of many different bearing con-

FB-1225

figurations, while sufficiently complete to compare very well against experimental measurements in all respects.

A comparison is made between the recessed and nonrecessed bearing.

ASME Paper No. 61-LUB-15, "Analytical and Experimental Study of Externally Pressurized Air Lubricated Journal Bearings," presented at the ASLE-ASME Lubrication Conference, Chicago, Oct., 1961, 8 pp.

management

Engineering Records Systems Based on Microfilm

D. W. McArthur, manager, Microfilm Products, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

When and how to systemize engineering records by means of microfilm.

To a great extent, the product a company manufactures determines how it will implement microfilming of engineering records. The goods-producing processes that make up the hardware and supplies for such an automated system are not many.

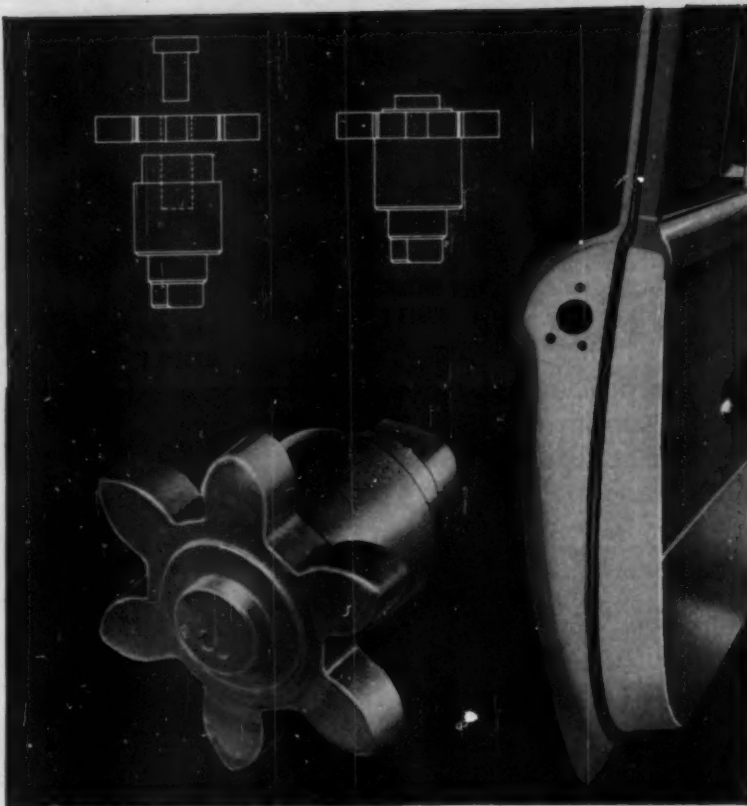
On the other hand, the customer-satisfying processes to adapt these items of hardware and supplies to a company's specific needs are infinite and varied.

There is a common factor for systemizing engineering records. The components of this factor are a reproducible medium plus an automated carrier. The reproducible medium that converts all engineering drawings to both a uniform size and a uniform photographic quality is 35-mm microfilm. The carrier is a punch card.

This system has three inputs and three outputs. These inputs and outputs can affect a drawing from the time an engineering order is approved until long after the part is obsolete.

The inputs are microfilming, indexing, and mounting or film insertion into the cards. The outputs are distribution, reference, and reproduction. The proper approach to implementation is to work backward from the requirements of distribution, reference, and reproduction to the inputs of microfilming, indexing, and mounting.

ASME Paper No. 61-PET-12, "Factors in



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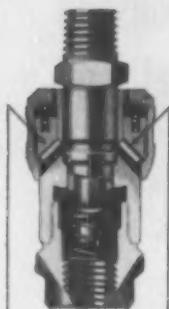
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Here's the fluid line coupling that can really take it. The ability of Hansen Push-Tite Couplings to withstand severe service—with practically no maintenance—has been thoroughly proved by years of hard, everyday use on literally thousands of fluid line circuits.

To connect a Hansen Push-Tite Coupling, you merely push the Plug into the Socket—as easily as plugging in your electric shaver. Flow is automatic—instantaneous. Plug swivels freely—no kinking of hose. To disconnect, pull back sleeve on Socket. Instantly and automatically, Socket shuts off flow of air or liquid.

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DESIGN ABSTRACTS

Automating Engineering Graphics," presented at the Petroleum Mechanical Engineering Conference, Kansas City, Mo., September, 1961, 12 pp.

Appearance Design of Agricultural Equipment

John Gale, G. T. Scharfenberg, and
J. N. Polivka, partners, Scharfenberg-
Polivka-Gale, Inc.

The role of the industrial designer in the design of farm equipment.

Correct design of a piece of farm equipment must amplify the basic function of the machine, which is to supply or use power ruggedly and assuredly. On larger machines the brutish look can even be accented.

Many factors must be considered in addition to the basic function of the machine. Comfort and human engineering must be considered not only as they affect the operator but also as they are conducive to ease of maintenance.

A key consideration is the end cost of the product. It is often possible for the designer to suggest refinements which will result in cost reductions. If he is doing his job properly, he will be constantly alert for areas where parts can be eliminated, simplified, or made common with some other component. He should be able to suggest new techniques and materials. As an outsider, a designer can make an unbiased examination of the traditional policies and methods some firms impose on the organization engineer.

In addition to all the other factors, the industrial designer must consider competition. What products are currently on the market? What new developments might other manufacturers have on the drawing boards? How are these new products likely to affect the sale of our own?

SAE Paper No. 404B, "Farm Equipment: A Growing Challenge for the Industrial Designer," presented at the Heavy-Duty Vehicle Meeting, Milwaukee, September, 1961, 10 pp.

hydraulic

Fluid-Linked Steering Control

David F. Morgan, product manager,
Power Steering, Char-Lynn Co.

Design and operation of a hydrau-

lic control which makes fluid-linked systems practical.

This control uses a rotary displacement device to measure the volume of fluid being metered to a remote actuator. Integral valving controls delivery direction and determines the system demand. The input shaft of the unit usually is connected directly to the steering wheel.

In a typical system, the remote actuator can be of any fixed displacement design. A single, plain, power-steering cylinder is most commonly used. A rotary cylinder, hydraulic motor, or a pair of power steering cylinders could serve the same purpose.

In addition to the control and the actuator, the typical system includes a power steering pump and fluid feed lines which couple the power circuit and the controlled or actuator circuit.

In basic component functions, the control comprises a rotary displacement gear, feed and distribution system for the metering gear, directional control valving for the powered circuit, and the mechanical housing combination of these in a compact usable form.

Typical construction machine application is 12½ ton pneumatic compactor. On this, the steered axle comprises five pneumatic roller tires, 7.50 x 15 size. The total steered axle load is about 13,900 lb. A belt-driven power-steering pump, flow-controlled to deliver 6 gpm and pressure relieved at 1250 psi, powers the system.

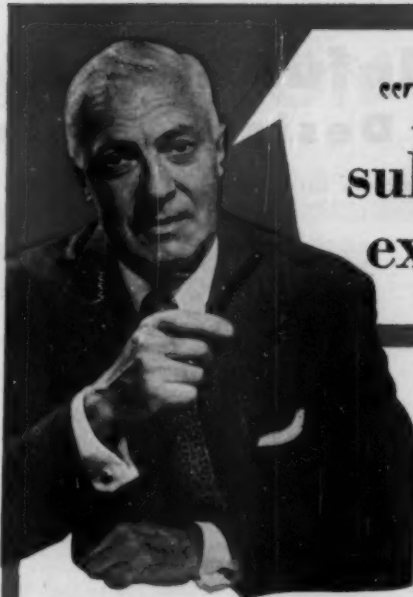
SAE Paper No. 400A, "Full Fluid Steering Control," presented at the Heavy-Duty Vehicle Meeting, Milwaukee, September, 1961, 7 pp.

TO OBTAIN COPIES of papers or articles abstracted here, write directly to:

ASLE—American Society of Lubrication Engineers, 5 North Wabash Ave., Chicago 2, Ill.; papers 50 cents to members, 75 cents to nonmembers.

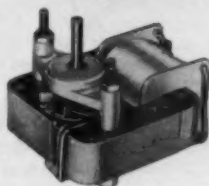
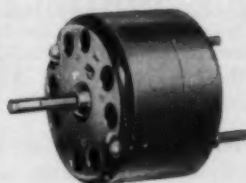
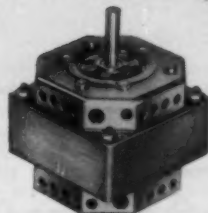
ASME—American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York 17, N. Y.; papers 50 cents to members, one dollar to nonmembers.

SAE—Society of Automotive Engineers, Inc., 485 Lexington Ave., New York 17, N. Y.; papers 50 cents to members, 75 cents to nonmembers.



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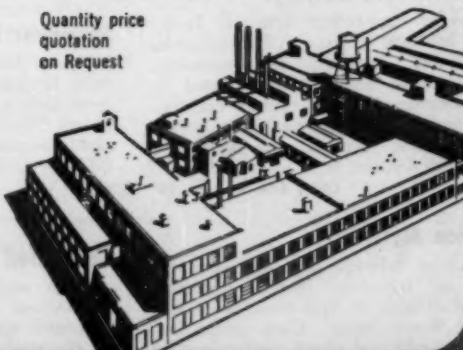
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Helpful Literature for Design Engineers

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Meter-Relays

Describes locking-contact meter-relays, including operating features, specifications, and standard circuits for achieving the most popular types of control action. Bulletin also covers isolated coils, double-locking coils, response time and damping, overload protection, and control components used with meter-relays. Bulletin 5, 24 pages. Assembly Products Inc., Chesterland, Ohio.

Circle 501 on Page 19

Industrial Gas Data

Lists physical and chemical properties of oxygen, nitrogen, argon, helium, hydrogen, carbon dioxide, acetylene, neon, krypton and xenon. Similar information is included on ethylene, nitrous oxide, and cyclopropane. Conversion tables provide a fast method for changing volumetric information on the various industrial gases from one equivalent unit of measure to another. Also includes capacity data on industrial gas delivery and storage systems. Form ADE-890, 48 pages. Air Reduction Sales Co., Div., Air Reduction Co. Inc., 150 E. 42nd St., New York 17, N. Y.

Circle 502 on Page 19

Precision Resistors

Provides data on Cal-R wirewound power resistors. Includes list of outstanding features, and suggests uses for the various units. Contains chart of specifications, curves, standard ranges, tolerances, resistances. 16 pages. California Resistor Corp., 1631 Colorado Ave., Santa Monica, Calif.

Circle 503 on Page 19

Self-Lubricated Bearings

Provides engineering data on Lube-Align bearings, consisting of a one-piece, self-aligning, integrally cast, spherical, self-lubricating bronze bearing nested in an aluminum housing. Points out features and choice of mountings in a wide range of sizes. 8 pages. Bronze Bearing Inc., 3353 Addison St., Chicago 18, Ill.

Circle 504 on Page 19

Friction Materials

Contains technical data and specifications on industrial friction materials. Covers selection of right brake block, lining, or clutch facing. Gives design factors for brake and clutch mechanisms, as well as a list of minimum diameters to which roll linings should be formed. Discusses materials recommended for special industries, and explains recom-

mended practices for riveting, key-locking, and bonding the materials. Catalog FM-57A, 24 pages. Packing & Friction Materials Div., Johns-Mansville Corp., 22 E. 40th St., New York 16, N. Y.

Circle 505 on Page 19

Interlocking Tube Files

Contains facts on Interlock filing system for drawings, patterns, prints, maps, and other documents. Answers questions on economy, space requirements, fire resistance, convenience, installation layouts, and accessories. 28 pages. Pack Mfg. Co., P. O. Box 508, Logan, Utah.

Circle 506 on Page 19

Tachometer Systems

Describes complete tachometer systems, including tachometer generators, tachometer indicator, and various drives to connect the tachometer generators to industrial machinery, motors, engines, and other rotating equipment. Bulletin also shows enclosures for wall mounting for the tachometer indicators. Tachometers are available in a variety of speed ranges, in several types and sizes of indicators and generators. Herman H. Sticht Co. Inc., 24 Park Place, New York 8, N. Y.

Circle 507 on Page 19

Air Cylinder

Describes Squair Head cylinders with 1½ through 14-in. bores. Provides dimensions and engineering data on the air cylinders and shows how with minor modifications they can be adapted for low-pressure hydraulic service. Includes data on cylinder accessories. Bulletin SQ-61, 48 pages. Tomkins-Johnson Co., 2425 W. Michigan Ave., Jackson, Mich.

Circle 508 on Page 19

Spur-Gear Racks

Covers precision fine-pitch spur gear racks in eight diametral pitches. Gives specifications for Precision 1, 2, and 3 classes. Shows how to butt two or more racks to make longer lengths. 8 pages. PIC Corp., 426 Atlantic Ave., East Rockaway L. I., N. Y.

Circle 509 on Page 19

Laminated Plastics

Gives engineering data on laminated plastics and vulcanized fiber for the selection and application of these materials in electrical, electronic, and mechanical applications. Covers 25 common grades of laminated plastics and 6 grades of vulcanized fiber. Special grades of vulcanized fiber are also described. Form

SW 62, 8 pages. Taylor Fibre Co., Norristown, Pa.

Circle 510 on Page 19

Recorders

Describes line of direct and servo-operated switchboard and portable recorders. Includes information on 19 types of single and multipen, ink and inkless, strip and round-chart recorders. Recorders are described in accuracy classes of ¼, 3/10, 1, 2, and 3 per cent. Lists electrical and physical parameters that can be measured by the recorders in various applications. Includes specifications, dimensions, applications, features, operating data, and optional accessories. Bulletin GEA-6933A, 12 pages. General Electric Co., Schenectady 5, N. Y.

Circle 511 on Page 19

Vane Pumps

Discusses use and operating characteristics of Series TIC vane pumps at pressures to 2500 psi. Shows a variety of possible applications in hydraulic circuits, and includes performance and efficiency charts and schematic diagrams. Also provided is a tabulation of typical pump operating characteristics. Bulletin 200-A, 8 pages. Denison Engineering Div., American Brake Shoe Co., 1160 Dublin Rd., Columbus, Ohio.

Circle 512 on Page 19

Thin-Section Bearings

Describes thin-cross-section bearings used in equipment operating at low or oscillating speeds under light to moderate loading. Illustrates a typical bearing mounted in rotating electronic equipment, and describes OD/ID dimensions, material, and production tolerances. Bulletin 8, 2 pages. Industrial Tectonics Inc., 18301 Santa Fe Ave., Compton, Calif.

Circle 513 on Page 19

Nonferrous Casting Alloys

Describes 40 nonferrous alloys most frequently specified for centrifugal castings. Covers aluminum bronze, gear bronze, bearing bronze, manganese bronze, nickel, silver, and special alloys. Nominal chemical compositions are presented for each alloy, as well as minimum and typical mechanical properties, including calculations for Brinell hardness, elongation, tensile, and yield strength. More than 100 similar governmental and society specifications are also shown. Bulletin 100, 4 pages. Wisconsin Centrifugal Foundry, 905 E. St. Paul Ave., Waukesha, Wis.

Circle 514 on Page 19

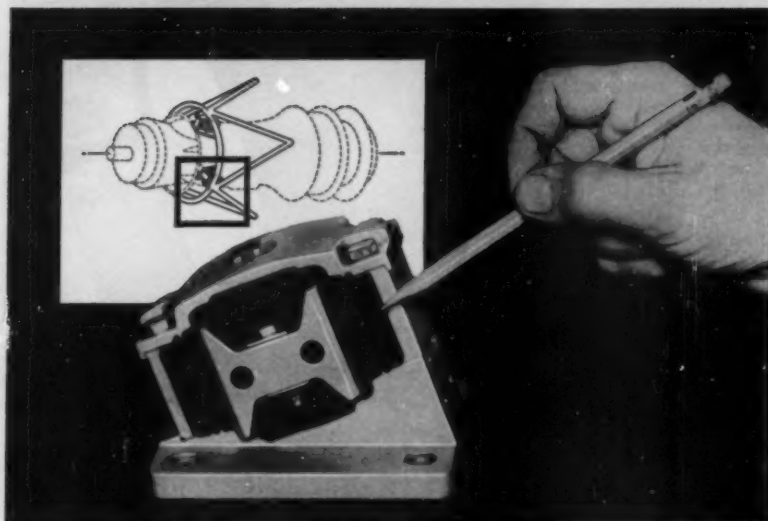


VIBRATION NOTES

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New MB Synthetic Coating Solves Tough Engine Mount Problem

How do you isolate the vibration of an aircraft engine when none of the available engine mount materials can meet the specifications required? MB engineers had to solve this problem in designing mounts for the turboprop engines of the Grumman Mohawk observation plane. They did it by "manufacturing" a new isolation material... natural rubber covered with a thin film of Iso-Kote, a unique elastomeric coating.

Vibration isolators for the turboprop engine had to withstand high gyroscopic loads; were limited in size by dimensions of engine mounting pad and nacelle structure; and had to be resistant to di-ester lubricant, Turbo Oil #15. Mechanical requirements left no room for compromise. Only natural rubber could meet the rigid specifications of strength, weight, space limitations and low temperature flexibility.

However, natural rubber deteriorates upon exposure for any length

of time to the di-ester Turbo Oil. So, unfortunately, do those synthetics generally considered for vibration isolation.

The application of a thin coating of Iso-Kote to natural rubber provided complete resistance against the corrosion and degradation effects of the di-ester lubricant. The coating has excellent adherence and, of particular importance in vibration applications, has the same elongation as natural rubber.

The successful development of this unique engine mount material, combining the mechanical properties of natural rubber and the chemical properties of Iso-Kote, represents another MB achievement in vibration engineering.

MB engineers will be glad to assist you in solving your vibration problems. Send today for our Vibration Mount Catalog. Write to Iso-mode Division, MB Electronics, P.O. Box 1825, New Haven 8, Conn.

Fundamental Motions of Vibrating Bodies

Isomode is the registered trademark of MB's regular line of vibration mounts. The name is derived from the word "isolation" and from the six "modes" of motion to which all rigid bodies are subject.

In actual practice, vibration is seldom confined to a simple, single motion. If it were, control would become a fairly simple matter. But even a rigid body has six degrees of freedom in space as illustrated here.

Complex structures have even more modes of motion. These may involve the relative motion of various rigid bodies or distortion of flexible bodies.

In general, vibration problems lie in the six fundamental motions. Any of these modes may be excited by vibratory forces. To design successful vibration control, you must consider all modes and the excitations to be expected.

1. Translation along longitudinal axis



2. Translation along lateral axis



3. Translation along vertical axis



4. Rotation about longitudinal axis (roll)

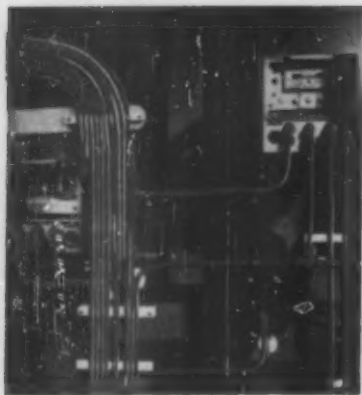


5. Rotation about lateral axis (pitch)



6. Rotation about vertical axis (yaw)





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Circle 296 on Page 19

HELPFUL LITERATURE

Power Metal Film Resistors

Type PMF resistors have inherent stability and withstand severe environmental conditions. Bulletin includes full performance specifications and points out features of the units. Bulletin P-9, 2 pages. International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.

Circle 515 on Page 19

Universal Joints

Describes Series J universal joints designed for heavy-duty applications. Four sizes have torque capacities from 4250 to 12,700 lb-ft. Six different types in each size are fully described. Bulletin 513, 6 pages. Hydraulic Div., Twin Disc Clutch Co., Rockford, Ill.

Circle 516 on Page 19

Precision Test Instruments

Lists line of integrated sound, vibration, and data-analysis instrumentation. Includes accelerometers, amplifiers, deviation bridges, voltmeters, level recorders, microphone equipment, oscillators, and strain-gage equipment. Catalog ES-10, 24 pages. B & K Instruments Inc., 3044 W. 106th St., Cleveland 11, Ohio.

Circle 517 on Page 19

Snap-Action Switches

Lists and describes full line of basic snap-action switches. Includes illustrations, technical data, and ordering information. Defines terms used in descriptions of switches. 20 pages. Cherry Electrical Products Corp., P. O. Box 66, Highland Park, Ill.

Circle 518 on Page 19

Reinforced Plastic Parts

Shows design possibilities for molding parts of reinforced plastics with integral electric heaters. Describes various types of laminations, typical molded parts, and gives performance curves for different laminations and electrical inputs. Form 101, 4 pages. Bischoff Chemical Corp., 220 Miller Rd., Hicksville, N. Y.

Circle 519 on Page 19

Self-Contained Recorder

Describes Impact-O-graph mechanical, three-directional impact, acceleration, and gravity recorder. Lists several models, gives typical ranges and frequency responses, and includes specifications and features. 4 pages. Impact-O-Graph Corp., B. F. Keith Bldg., Cleveland 15, Ohio.

Circle 520 on Page 19

Hydronic Valve

Describes valves for hydronic heating and cooling systems. Covers specifications and descriptions of Hydrozone motorized zone valves, reducing valves for hydronic boilers, ASME pressure-relief valves for hydronic boilers, and complete series of dual controls. Bulletin HYD-1, 12 pages. Cash-Acme, P. O. Box 191, Decatur, Ill.

Circle 521 on Page 19

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Band is slipped over hose, duct or fitting — then through housing. A downward snap of the swivel screw locks clamp in position for screwdriver tightening. Application is easy, fast, positive.

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Circle 297 on Page 19

Convertible Trouble Free Contacts...Tens of Millions of Operations

Bulletin Type BR Control Relay with one pole changed over to the normally closed position.

Type B General Purpose 8 Pole Control Relay

Type BX 4 Pole Construction Universal Relay

NEMA Type 1 Enclosure for all Relays

In 9 out of 10 cases the Type BR Relay will far outlast its original service application

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The molded coil is impervious to *all* harmful atmospheres. And the double break, silver contacts—standard on all A-B relays—never need attention of any kind.

The popular Allen-Bradley Type B, general purpose, and Type BX, universal, relays incorporate many advanced features to insure long, trouble free life. The new structural design increases mechanical life *at least 5 times*. A new contact motion increases electrical reliability *at least 10 times*.

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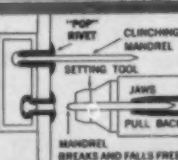
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Circle 299 on Page 19

HELPFUL LITERATURE

DC Solenoids

Covers several models of standard solenoids. Includes general description with characteristic curve and pull curve. Also covers remote solenoid controls, and gives all mounting dimensions. Bulletin 605, 4 pages. Synchro-Start Products Inc., 8151 N. Ridgeway Ave., Skokie, Ill.

Circle 522 on Page 19

Hydraulic Filter

Tell-Tale filters for suction-line use in hydraulic systems are described and illustrated. Includes a large cutaway drawing showing all major parts. Dimensional data are given for all models, and instructions for ordering are presented. Models with electrical indicators and magnetic filters are also discussed. Vickers Inc., Div., Sperry Rand Corp., Detroit 32, Mich.

Circle 523 on Page 19

Electric Motors

Describes 25 ac and dc precision motors designed for industry and for such applications as airborne communication equipment, business machines, computers, blowers, special electronic equipment, and tape recorders. Motors are available in sizes from 0.001 to 7.5 hp. Specifications for each unit, such as input and output voltage, design standards, size and weight, and insulation are provided. 26 pages. Eicor Div., Indiana General Corp., 517 W. Walnut St., Oglesby, Ill.

Circle 524 on Page 19

Extension Springs

Provides description of each of 21 standard Negator constant-force extension springs available from stock. Intended primarily as an experimental tool for the design engineer, units can prove useful for production applications requiring a noncritical constant retracting force to be delivered through long deflections. Includes such data as material thickness, width, length, working deflection, load, and life. Advance Bulletin A310X, 2 pages. Hunter Spring Co., Div., American Machine & Metals Inc., Lansdale, Pa.

Circle 525 on Page 19

Monitoring Systems

Shows four systems for monitoring radioactivity, each with a specialized function. Points out features necessary to a reliable monitoring system. Bulletin M-62, 4 pages. Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Circle 526 on Page 19

Hydraulic Equipment

Provides data on hand and foot-operated Hi-Lo hydraulic pumps, in single and double-piston types. Also covers hydraulic rams and high-pressure cylinders, and specialties. Bulletin 160, 8 pages. Star Hydraulics Inc., River Grove, Ill.

Circle 527 on Page 19

Gear Motors

Illustrates unidirectional and reversible gear motors. Gives typical applications, diagram drawings, dimensions and specifications of each motor type. Also illustrates many special-purpose designs and adaptations of the gear motors. Includes data on a new, small, compactly designed gear motor available in four stator sizes. Catalog 1061, 6 pages. Electro Counter & Motor Co., 2717 N. Ashland Ave., Chicago 14, Ill.

Circle 528 on Page 19

Blowers and Pumps

Presents line of rotary, positive-displacement blowers (Type RAS) and gas pumps (Type RGS). Outlines the advantages of the heavy-duty machines, presents data on performance and operating characteristics. Details 36 sizes with capacities from 1500 to 30,000 cfm, working pressures to 12 psig, and dry vacuums to 15 in. Hg. Bulletin RAS-261, 8 pages. Roots-Connorsville Blower Div., Dresser Industries Inc., 900 W. Mount St., Connorsville, Ind.

Circle 529 on Page 19

Power Foot Switches

Lists line of power foot switches designed for industrial and commercial applications. Covers various types, describes design details, and gives specifications. Catalog 62, 8 pages. Linemaster Switch Corp., 432 Woodstock Terrace, Woodstock, Conn.

Circle 530 on Page 19

Circuit Breaker

Describes Type 550 circuit breaker, a hydraulic-magnetic unit for use in electrical and electronic equipment where fractional ampere ratings and relatively low currents are required. Publication presents test data, electrical ratings, trip ratings, and typical specifications. Bulletin 29-550, 4 pp. Standard Control Div., Westinghouse Electric Corp., Beaver, Pa.

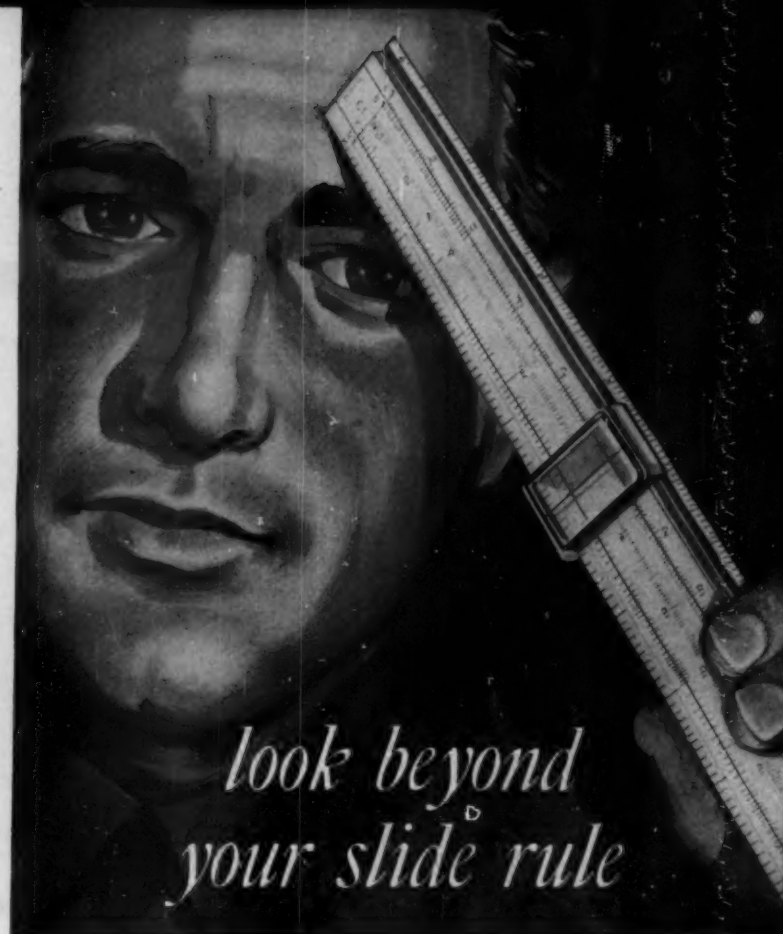
Circle 531 on Page 19

Air Cylinders

Illustrates and describes operation and application of air cylinders. Contains description of Squaremaster air cylinders, and includes engineering drawings and specifications of the eight mounting styles available. Manual 10, 16 pages. Write on company letterhead to Rivett Lathe & Grinder Inc., Brighton 35, Boston, Mass.

Industrial Finishes

Describes silicone-based industrial finishes and their capabilities. Contains photographs of comparative testing of silicone high-temperature coatings and other coatings under a variety of test conditions, as well as in actual applications. Included are discussions on range of colors available, and information on applications. Booklet CDS-294, 16 pages. Write on company letterhead to Silicone Products Dept., General Electric Co., Waterford, N. Y.



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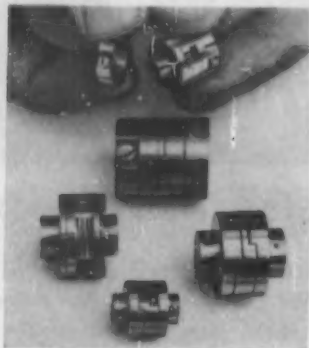
New Parts and Materials

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Oldham Couplings

have backlash tolerance
of 8 min of arc

Stainless-steel Oldham couplings, now available from stock, permit as much as 1/32-in. axial misalignment of shafts. Units have a backlash tolerance of 8 min of arc. Couplings are available in more than 60 different combinations of clamp and solid-type hubs. They can be used



to couple different size shafts, ranging from 0.125 to 0.250-in. diam. Dynamic Gear Co. Inc., Amityville, N. Y.

Circle 532 on Page 19

Silver-Cadmium Button Cells

in six capacities from
0.25 to 6 amp-hr

Silcad hermetically sealed, rechargeable, silver-cadmium button cells are available for evaluation. A little larger in diameter than a half-dollar, the maintenance-free cells have up to 75 per cent more capacity than standard rechargeable button cells of the same size, and a cycle life almost 60 per cent greater. Six capacities are available, from 0.25 to 6 amp-hr. Cells demonstrate excellent capacity retention. Flat discharge voltage assures constant performance of the equip-



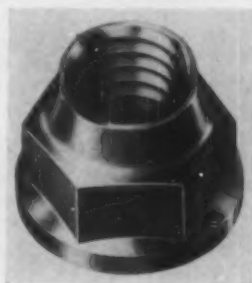
ment into which they will be designed, and low internal resistance permits high peak discharges. Cells can be used over a wide range of temperatures, and in any position without leakage. They can be manufactured in nonmagnetic types. Open-circuit cell voltage is 1.4, nominal voltage under load, 1.1 v. Yardney Electric Corp., 40-50 Leonard St., New York 13, N. Y.

Circle 533 on Page 19

One-Piece Lock Nut

in sizes from No. 10 to 1/2 in.

Lokon one-piece, all-metal lock nut of prevailing-torque type is available in sizes from No. 10 through 1/2 in., UNC and UNF threads; other sizes will be available. Nut is heat-treated alloy steel which gives high strength without bulk and imparts elasticity to permit reuse. Locking is effected by a slight deformation of the top threads into elliptical shape. As nut is assembled, out-of-round threads tend to conform to the circular pattern of the



mating threads. Friction on the flanks of the nut threads is thus increased to create a positive locking grip. Nut resists temperatures to 550 F and has tensile strength over 250,000 psi. Lokon Locknut Div., Allen Mfg. Co., Hartford 1, Conn.

Circle 534 on Page 19

Semiconductor Networks

in six different
digital-circuit modules

Series 51 Solid Circuit semiconductor networks include six different digital-circuit modules which handle 90 per cent of the circuit functions of digital equipment, particularly for military computers, programmers, and other information-processing application functions. Each silicon network is contained in a hermetically sealed package measuring 1/4 x 1/8 x 1/32-in. Networks perform flip-flop, counter,



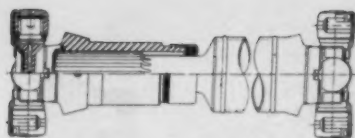
NOR gate, NAND gate, and exclusive OR-gate functions. They operate over a temperature range of -55 to +125 C. Texas Instruments Inc., P. O. Box 5474, Dallas 22, Tex.

Circle 535 on Page 19

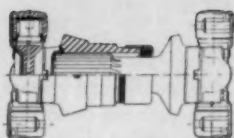
Metallic Static Seals

for all standard AN cavities

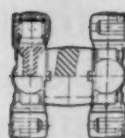
Apex seals incorporate a reinforced section which increases strength to



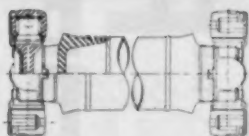
Type "TS"—with tube and slip



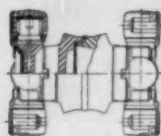
Type "CS"—with slip and without tube
—close coupled



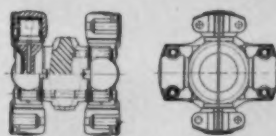
Type "CP"—with coupling plate and
without slip—close coupled



Type "T"—with tube and without slip



Type "CY"—without tube and slip—
close coupled



Type "CP7"—with coupling plate and
without slip—extra close coupled

NEW

TWIN DISC
POWER TRANSMISSION EQUIPMENT

GWB

UNIVERSAL JOINTS

Torque capacities from 4,250 to 12,700 lbs.-ft.

Through a license agreement with GWB of Germany, Europe's largest manufacturer of heavy-duty universal joints, Twin Disc is now building U-joints for the American market which incorporate all the outstanding features of GWB's time-tested design. These include caged needle bearings with relieved end needles, double-lip seals, nylon thrust bearings and tapered-shoulder trunnions.

Twin Disc-GWB joints are offered in four sizes, two of which — the J-230 and J-310 — are currently in production. The other two — the J-170 and J-490 — are scheduled for production early in 1962. Each size includes six different types of varying lengths in slip and non-slip designs.

The life expectancy of a U-joint is essentially an expression of the life

expectancy of its roller bearings. Obviously, the larger the bearings, the longer the useful life of the joint, and — size for size — Twin Disc-GWB Joints feature larger bearings than competitive units.

This is made possible by the high-wing bearing design of all Twin Disc-GWB assemblies. High-wing bearings permit use of a maximum diameter bore in the bearing cap to accommodate a larger bearing *without increasing swing diameter*. This is an



important consideration to designers who are now experiencing unsatisfactory U-joint performance yet do not have space for a larger size.

For complete engineering details on Twin Disc-GWB "J" Series Universal Joints, request Bulletin 513. Twin Disc engineers will be glad to make recommendations for "J" Series assemblies as replacement units as well as for new applications. Contact the Application Engineering Dept., TWIN DISC CLUTCH COMPANY, Hydraulic Division, Rockford, Illinois.

RATED CAPACITY

Size	Max. Oper. Torque (lbs.-ft.)	Dynamic Factor	Static Factor
J-170	4,250	16.6	5.05
J-230	6,100	22.98	7.32
J-310	8,400	31.40	10.00
J-490	12,700	49.00	15.15

How Curtis helped a design engineer "BEAT THE HEAT"



This single universal joint in a ribbon-stripping machine was operated at a 34° angle. The joint heated up, wear was excessive. (Curtis Joints have been tested at angles up to 37°, but we do not ordinarily recommend angles greater than 30°.)



Curtis engineers recommended a double Curtis joint, which reduced the angle to 17° per joint. Result: no overheating, improved efficiency, longer life.

You can depend on Curtis engineering in any problem of angular power transmission. And you can depend on

CURTIS UNIVERSAL JOINTS

because our catalog torque and load ratings are substantiated by constant tests under production conditions.

14 SIZES ALWAYS IN STOCK —

3/8" to 4" O.D. (6" joints on special order)

Not sold through distributors. Write direct for free engineering data and price list.

TRADE
© **CURTIS**
MARK
UNIVERSAL JOINT CO., INC.

311 Birnie Avenue, Springfield, Mass.

As near to you as your telephone

EXCLUSIVELY A MANUFACTURER OF
UNIVERSAL JOINTS SINCE 1919

Circle 302 on Page 19

NEW PARTS AND MATERIALS

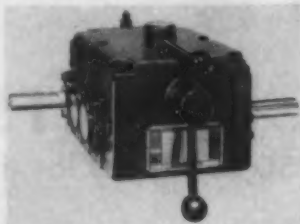
produce zero leakage, while maintaining low compressive force. Pressures from vacuum to over 30,000 psi can be sealed from -320 to +2200 F. Lower flange loading often results in size and weight reductions. Zero leakage is obtained by balancing the physical properties of the seal coating material against the compressive force on the seal, forcing coating into the tool marks in the seal cavity. Seals are available for all standard AN cavities and can be supplied in many irregular sizes or configurations. Servotronics Inc., 190 Gruner Rd., Buffalo 25, N. Y.

Circle 536 on Page 19

Reversing Transmissions

in sizes from 2 to 75 hp

New reversing transmissions are available in seven standard sizes from 2 to 75 hp. Hinged motor-mounting plate and mounting base are available for compact installa-



tion. Transmission features Turner shaft location and mounting arrangements, plus splash-lubricated bearings and gears. Turner Uni-Drive Co., 3416 Terrace St., Kansas City 11, Mo.

Circle 537 on Page 19

One-Component Adhesive

for temperatures from
-70 to +200 F

Scotch-Weld EC-2086 and EC-2186 one-component, modified epoxy-resin-base adhesives provide high impact, peel, and bend strength, and will not run or flow on vertical surfaces during heat-curing operations. Designed for bonding structural, metal, and plastic parts, adhesives maintain high-strength properties at service temperatures from -70 to +200 F. Paste-type consistency provides excellent void-filling prop-

THE **FREE**
M **WOOD**
DIMENSION



... saves 35
machining operations

This target revolver barrel is now being made by the new Hitchiner Ceramic Shell technique of investment casting. Thirty-five machining operations are eliminated! The only external finishing required is partial polishing.

Investment casting may provide many benefits for you... choice of alloy... flexibility of design... improved parts performance... reduction of costs. Maybe one of your parts can be made better for less.



Write for
complete
technical
and facilities
information.

HITCHINER
Milford 3, New Hampshire

Circle 303 on Page 19

HOW TO MEASURE A NOISE YOU CAN'T HEAR

Vibrations detected by a sensitive pickup, then amplified and analyzed by electronic equipment, enable SKF engineers to measure almost imperceptible noises occurring in rotating ball and roller bearings. Based on long-continued investigation, noise and vibration appear to be almost solely the result of minute deviations in the surface geometry of the rolling elements and rings. Detection of this surface "waviness" as a source of bearing noise is an important SKF contribution towards solving the problem of producing quieter, smoother running bearings. Methods developed for minimizing waviness have already resulted in the quietest bearings yet made for electric motors and other equipment, as well as even greater precision in the high quality bearings for aero-space and similar applications.

Advanced research is one of the reasons why SKF maintains its leadership in producing finer rolling contact bearings. Whatever bearings you need—ball, cylindrical roller, spherical roller, tapered roller or precision miniature types—you'll find SKF your assurance of dependable performance. SKF Industries Inc., Philadelphia 32, Pa.

4102

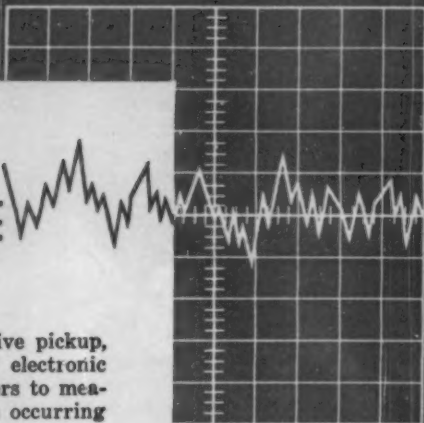
SKF

MOTION ENGINEERING



Advanced ball and roller bearing technology

Circle 304 on Page 19

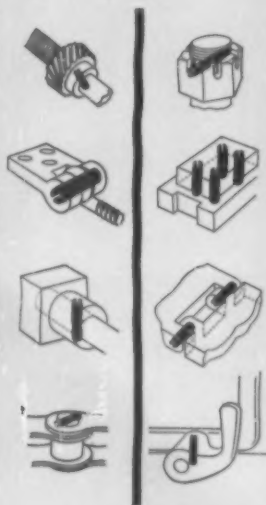


EVERY TYPE OF KEYING AND PINNING DEVICE FOR PRODUCTION ASSEMBLING

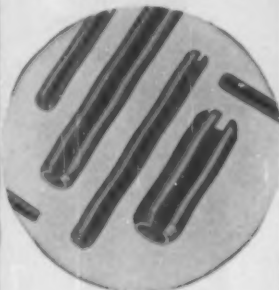
GILLEN

Self-Fitting TENSION PINS

Speed
Many Assemblies
and Stay Put!



Tension holds them Tight!
in Metal/Plastics/Ceramics



GILLEN TENSION PINS

are hollow, hardened, chamfered-end spring steel fasteners designed to hold many materials efficiently and reduce production-assembly costs.

Diameters: 3/64ths to 1 inch.
Lengths: from 3/16ths inch.

WRITE FOR STOCK SIZE
LIST & PRICES



JOHN GILLEN COMPANY
subsidiary of
STANRAY CORPORATION
2568 South 50th Avenue
Cicero 50, Illinois

GILLEN

PIVOTS • BUSHES • TENSION, TAPER, GROOVE & DOWEL PINS • MACHINE KEYS & PARTS

NEW PARTS AND MATERIALS

erties that permit structural bonding of loosely fitting parts. Adhesives, 100 per cent nonvolatile, are particularly useful for bonding impervious surfaces. They can be cured with contact pressure, and can be applied by knife coating, trowel, or high-pressure injection methods. Adhesives, Coatings, and Sealers Div., Minnesota Mining & Mfg. Co., 900 Bush St., St. Paul 6, Minn.

Circle 538 on Page 19

Prevailing-Torque Lock Nut

allows uniform
torque control

Morlok all-metal, prevailing-torque locknut gives positive locking action through the displacement of threads in three positions. Unit allows a uniform torque control, assuring freedom from burrs, material pick-up, and galling. It is made with a maximum wrenching hex and three



lobes compressed to make a circular configuration and gripping action on the bolt. Free-starting until locking action begins, nut assures easy selection and application for automatic feeding and hand assembly. True hexagon dimension is maintained the full height of the nut. Nut has Class 2B and 3B thread fits to provide for precision engagement, and is available in low and medium-carbon steels. Automatic Products Co., 1145 W. Grand Blvd., Detroit 8, Mich.

Circle 539 on Page 19

Electrolytic Potentiometers

for units needing
tilt indication

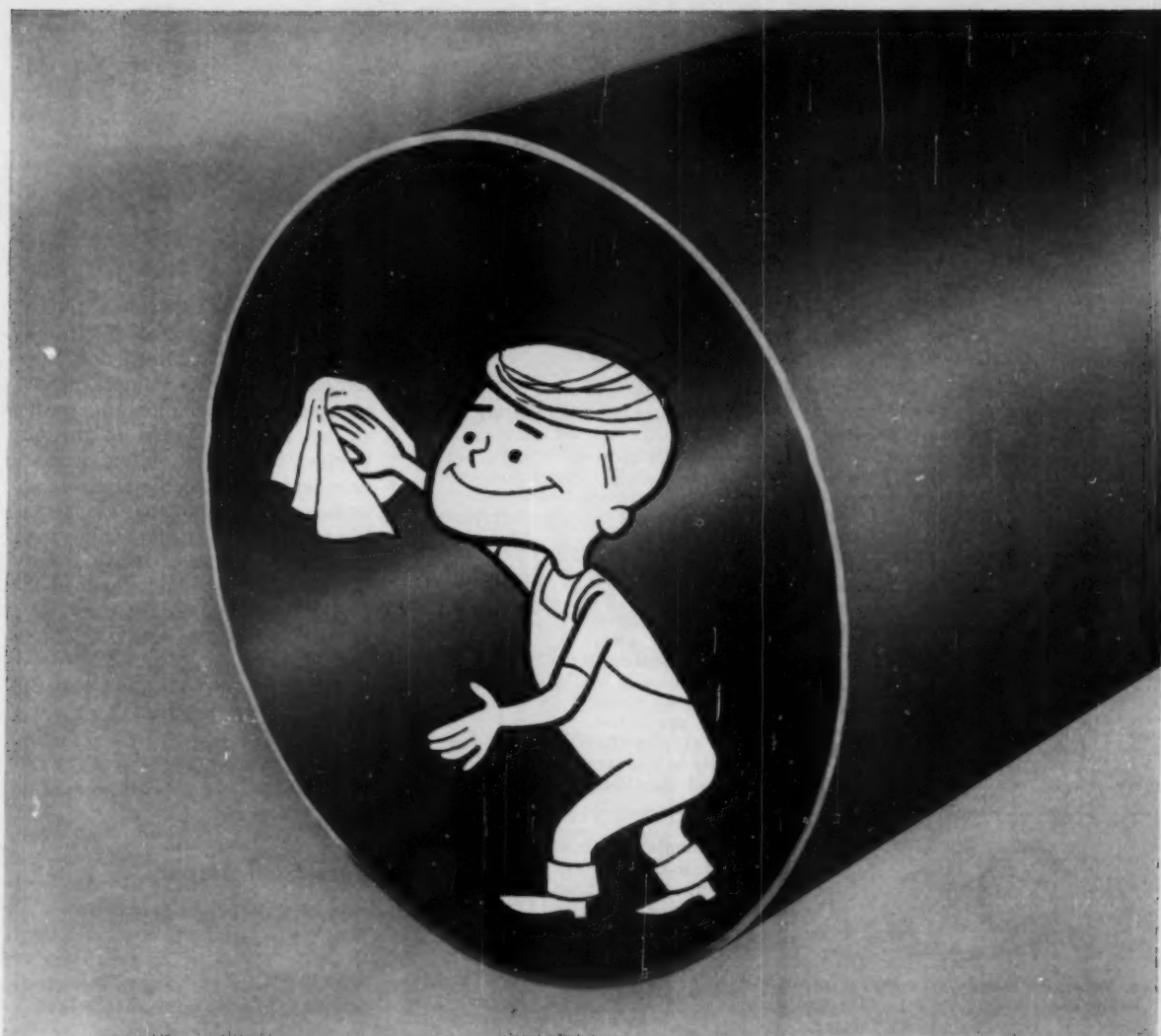
Series EP 100 gravity-sensing electrolytic potentiometers are available in eight different ratings. They are for use in gyroscope-correcting mechanisms, and in many other de-



WORK
BEST!

HYDRODYNE
INDUSTRIES
INCORPORATED

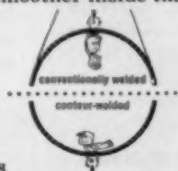
1080 BROADWAY
NEW YORK 10, N. Y.



**"The Gravity Kid" shows how
YOU CAN STOP CONTAMINATION WITH THE HELP
OF CONTOUR-WELDED STAINLESS TUBING**

In tubing, surfaces that are microscopically rough and ragged can cause contamination—simply because of the product becoming incrustated. Contour-welded tubing helps lick this problem because it's smoother inside than any other tubing, welded or seamless.

This smooth surface is the result of Contour-welding, a patented* process that eliminates the weld bead. Unlike conventionally-welded tubing, it's welded at the bottom. Gravity pulls the molten metal down so that the weld area corresponds to the inside contour of the tube. There's no bulge on the inside surface. Even on the outside, the seam closely



conforms to the tubing shape.

In conventionally-welded tubing, gravity pulls the molten metal down into the tube, forming a bead that is difficult to remove by cold working. And cold working can lead to undercuts that become focal points for incrustation.

Even seamless tubing isn't as smooth as Contour-welded tubing. That's because it's extruded or pierced, whereas Contour-welded tubing is formed from uniformly rolled strip steel.

But see for yourself. Write today for our free 48-page manual, which describes sizes from 1/8" to 40" O.D., in stainless and high alloy steels, titanium, zirconium, zircalloy, and Hastelloy**.

**Trademark Haynes Steelite Co.

* U.S. Patent 2,716,692

TRENTWELD® Stainless and High Alloy Tubing

Trent Tube Company, a Subsidiary of Crucible Steel Company of America, General Offices and Mills: East Troy, Wisc.; Fullerton, Calif.

the **NEG'ATOR** Data Book

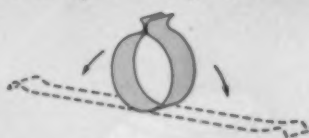
HUNTER
Spring in Spring

4.
CLIPS, CLAMPS
AND TUBES

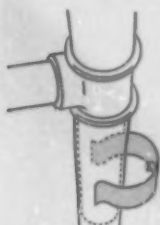
Using NEG'ATOR bands to fasten, retain, or clamp



1. A NEG'ATOR is a band of spring steel which is so prestressed in manufacturing that it exhibits a powerful tendency to curl—uniform throughout its length.

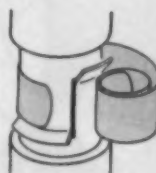


2. A fractional turn, partial coil, single coil, or several coils can be used as strong, resilient clips. Clips like these can be opened completely—even straightened—and will always re-coil to the same curvature.



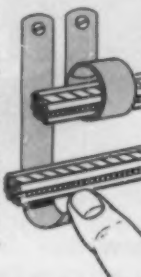
3. Again and again they can be opened wide and snapped into place without becoming "tired." And they can be furnished in various shapes and with special attachments.

4. The NEG'ATOR band can be "wrapped around" connecting members or joined parts where there is no access to ends. Once mounted, the clip holds snugly to the connected members.



5. When both ends of a NEG'ATOR band are allowed to form loops, the band becomes a powerful clamp wherein pressure exerted by the coils remains constant for any opening.

6. A simple NEG'ATOR band makes an excellent quick-acting loop or guide for cables, wires, or tubing in auto assemblies, wiring harnesses. Engagement or disengagement is fast, cable ends need not be accessible, and "give" is built into the clip.



7. Wide bands become tubes or drums of great strength and surface accuracy. They can be made tough or flimsy, bright or dark—can be printed and used as tapes or scrolls.

How to use them?

▪ Currently, NEG'ATOR clips, clamps, and tubes are being used as retainer rings, safety clips for explosive devices, protective shields, printed scrolls, recorder chart drums, electrical connector locks, scaffold locking clips, spool clips, cementing clamps, leaf springs, and in many other ways. Write for details on characteristics and applications.

The NEG'ATOR spring is a development of Hunter Spring Company.



HUNTER SPRING COMPANY

A Division of American Machine and Metals, Inc.

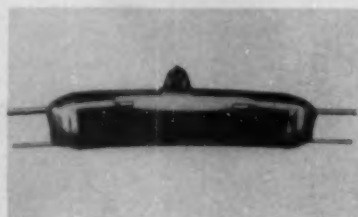
3 Spring Avenue, Lansdale, Pennsylvania

ULysse 5-6815

TWX: 982-U

DIVISIONS OF AMERICAN MACHINE AND METALS, INC.: Troy Laundry Machinery
Rohde Testing Machines • De Bortezat Fans • Telhurst Centrifugals • Filtration Engineers • Filtration Fabrics
Ningra Filters • United States Gauge • Rohm Instruments • Lamb Electric Co. • Hunter Spring Co. • Glaser-Stears Corp.

NEW PARTS AND MATERIALS



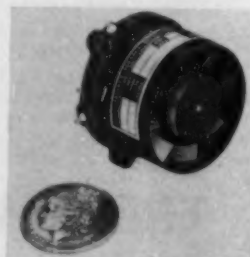
vices or controls requiring a gravity reference or tilt indication. Instruments consist of a curved-glass tube containing a predetermined amount of electrolytic solution to create an air bubble. Motion of the air bubble caused by tilting creates variable impedance by more or less immersion of the top electrodes. Electrical characteristics can be read on a remotely placed meter. Potentiometer provides highly damped action. Proportional output is obtained as the horizontal position is approached, enabling closer control with a servo system. Glass tube of the EP 108, shown, is 1 1/4 in. long, with a diameter of 9/32 in. Hamlin Inc., Lake Mills, Wis.

Circle 540 on Page 19

Vane-Axial Blower

for 400 cycle power
in 2-in. unit

VAX-2-MC 2-in. diam vane-axial blower produces up to 50 cfm at 2.1 in. water back pressure, and is designed for aircraft and missile use. Blower motor can be wound for 115 v ac, single or three phase, 400 cycles, or for 200 v ac, three phase, 400 cycles. Maximum power for the three-phase version is 45 w at 65 cfm free-air delivery. Low-speed version wound for 200 v ac, three-phase operation produces 23 cfm at 0.5 in. water back pressure and has life of over 3000 hr at temperatures to 125 C. Blower has a black anodized-aluminum precision cast-



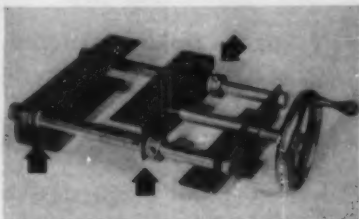
ing, and weighs 5 oz. Maximum length is $1\frac{1}{2}$ in. **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, Ohio.

Circle 541 on Page 19

Adjustable Motor Bases

for use on belt
drives to 1 hp

Quick, simple speed adjustment for fractional-horsepower drive assemblies using variable-pitch sheaves can be made with SB motor bases. Units have nylon bushings in the sliding rails for smooth traverse movement, and crosswise binding in bed travel is prevented by self-lubricating action of nylon on rigid



guide rods. Bases have heavy-duty screw adjustment and hand-wheel operation with locking collars to limit bed travel. Precision screw threading assures smooth, positive take-up without backlash. Model SB-2S is $7\frac{1}{2}$ x 10-in. size and has maximum 4-in. traverse; Model SB-2L is $7\frac{1}{2}$ x 12 in. long, with 5-in. traverse. Both are $2\frac{7}{16}$ in. high and have $4\frac{1}{2}$ -in. handwheel. **Rampe Mfg. Co.**, 14915 Woodworth Ave., Cleveland 10, Ohio.

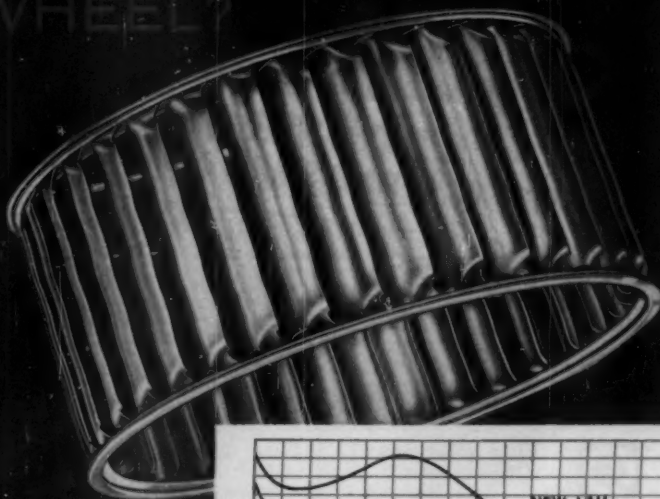
Circle 542 on Page 19

Silicon-Controlled Rectifiers

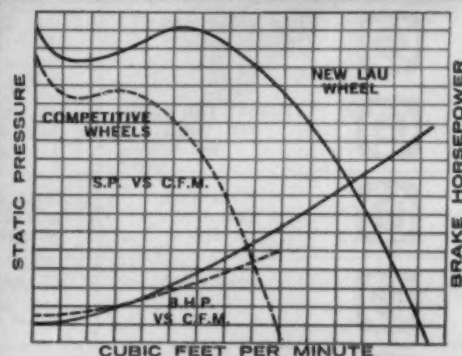
in eight models are
highly sensitive

No. C5 diffused, low-current, silicon-controlled rectifiers are available from stock in eight types with forward breakover voltages from 25 to 400 v. The sensitive devices are packaged in JEDEC TO-5 housings. Devices are used as both sensitive signal amplifiers and power-switching elements in low-power, switching-control circuits. C5 can also be operated as a high-voltage PNP transistor. Devices in the series accommodate transient peak-reverse

DO YOU NEED A HIGHER EFFICIENCY SMALL BLOWER WHEEL?



GET
INCREASED
PERFORMANCE
WITH THE NEW
LAU $4\frac{1}{4}$ to $8\frac{1}{2}$
SPUN WHEEL



Lau Engineering has successfully developed a blower wheel that out-performs any wheel of comparable size tested. This powerful, compact unit is specifically designed for installation in room air conditioners but can be used effectively in most appliance applications. Lau "spun" construction contributes greatly to the wheel's structural rigidity and to a very high CFM to WATT ratio.

This new Lau wheel is offered in a customer's choice of aluminum, cold rolled steel or zinc grip and in a range of diameters, blade lengths, bore sizes and back plate designs.

LAU

THE LAU BLOWER COMPANY

2027 Home Avenue

Dayton 7, Ohio

Mr. Wm. H. Wentling, Director of Engineering

The Lau Blower Co., 2027 Home Ave., Dayton 7, Ohio

Please send me your engineering data file on the new Lau high performing wheel. ☐ We would like to see sample wheel.

Name _____

Position _____

Company Name _____

Address _____










Get this free engineering data file on the new Lau high performance appliance wheel.

For saving benefits to
manufacturer and user

UNIFORMITY • SINGLE SOURCE
HIGH ACCURACY • LESS MAINTENANCE
LOW INITIAL COST • LESS DOWNTIME

standardize on the

ATCOTROL LINE OF 9 TIMERS AND COUNTERS

	AUTOMATIC RESET TIMER 305B	Up to 7 load circuits 16 standard dial ranges 14 point terminal block <i>bulletin N-305B</i>
	PUSH BUTTON RESET TIMER 309	1 or 2 SPDT load switches Best for batch control Cycle progress indication <i>bulletin N-309</i>
	TRANSISTOR TIMER 308	Long, dependable life .03—1.5 sec. to 1—150 secs. Remote dial setting <i>bulletin 1001</i>
	DUAL-SET TWO CYCLE DIAL TIMER 306	Two circuits, independently adjusted Safety dwell between reversals Full scale adjustability <i>bulletin N-306</i>
	PERCENTAGE DIAL TIMER 304	Heavy, 25 amp contacts Integral on-off switch provides adjustable rate control <i>bulletin N-304</i>
	REVOLUTION COUNTER 307	Counts shaft revolutions Long-life piece counting Cut-off control <i>bulletin 1000</i>
	PUSH BUTTON REVOLUTION COUNTER 312	Count control for rotating shafts From 0—12 to 0—240,000 revs at 2000 rpm <i>bulletin 1064</i>
	IMPULSE RESET COUNTER 310	500 counts per minute Exclusive impulse motor principle Accurate count selection <i>bulletin N-310</i>
	PUSH BUTTON IMPULSE COUNTER 311	Ranges 2—120, 4—240, 5—480, 10—960 For batch counting control 500 counts per minute <i>bulletin 1063</i>



Quick Delivery—for your convenience,
stocks of ATC Counters and Timers are main-
tained in principal cities for off-the-shelf delivery.

WRITE FOR BULLETINE

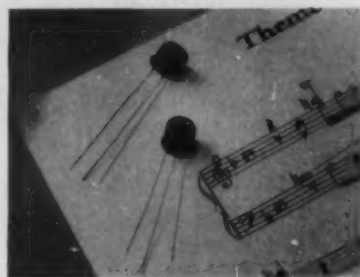
**AUTOMATIC TIMING
& CONTROLS, INC.**
KING OF PRUSSIA 2, PA.

A Subsidiary of American Manufacturing Company, Inc.

Export Department: 1505 Race St., Philadelphia 3, Pa.
In Canada: Interprovincial Safety Industries, Ltd.
5485 Notre Dame St., West, Montreal 30, Quebec



NEW PARTS AND MATERIALS



voltages to 500 v. Average forward
current rating is 1 amp dc at 82 C
case temperature. Maximum gate
current to fire is 200 ma amp at 25
C. Rectifier Components Dept., Gen-
eral Electric Co., West Genesee St.,
Auburn, N. Y.

Circle 543 on Page 19

Polyurethane Molding Material

can be cured in 3 min.

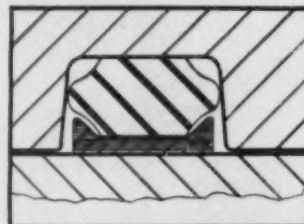
Vibrathane 5004 maintains excel-
lent processing characteristics when
it is cured at 350 F for 3 min.
Cured products have high abrasion
and tear resistance, good stress-
strain properties, high resistance to
dry-heat aging, good low-tempera-
ture performance, and excellent re-
sistance to ozone, oxygen, fuels, oils,
and chemicals. Suggested product ap-
plications include automotive parts,
conveyor-belt covers, hose, cable
jackets, molded industrial tires, oil-
well supplies, diaphragms, seals, and
gaskets. Naugatuck Chemical Div.,
United States Rubber Co., Nauga-
tuck, Conn.

Circle 544 on Page 19

Sealing Device

provides seal to 3000 psi
with no spiral failure

New dynamic sealing device, Plus
Seal, consists of an engineered Tef-
lon cap supported by an elastomer
ring with specially designed cross
section. Ring configuration provides



Denison and Denison HydrOILics are registered trademarks of Denison Eng. Div., ABSCO



Self-contained pumping units
furnish pressures up to 5000 psi,
flows to 122 gpm.

Packaged to help you ...

POWER-UP



HORIZONTAL TYPE PUMPING UNITS deliver constant or variable volumes up to 35 gpm at pressures up to 5000 psi. Available in 22 different models with 3 reservoir capacities—65, 110 and 165 gallons. Also available as JIC Series to meet exact specs—including reservoir capacities from 15 to 1000 gallons.

HYDRAULIC POWER IN A PACKAGE for today's design engineering demands is compact, efficient and economical in these Denison pumping units:

Vertical Types are standardized oil hydraulic units—employing Denison axial piston and vane type pumps—with volume capacities from 2 to 18 gpm at pressures from 800 to 3000 psi. Reservoir capacities from 5 to 35 gallons.

Motor (standard NEMA), pump, relief valve, oil level gauge and filler pipe are top-mounted on removable reservoir cover. Available in 3 basic models with 19 pump combinations—and with additional optional equipment including filter, pressure gauge, polyphase motors and water-cooled/thermostatically-controlled oil coolers. Dual units in 9 models are also available.

Horizontal Types (see photo) are high pressure units designed to meet a broad range of hydraulic power requirements. Six types of controls—from handwheel to servo—assure accurate delivery of any volume required.

Special Types offer giant reservoir capacities up to 1000 gallons. Accumulators are also available for instant response, holding, special circuits and other secondary functions. Accumulator capacities from 2½ to 10 gallons.

Write for Specifications Bulletins PU-3, PU-4, PU-5 and PU-6.

DENISON ENGINEERING DIVISION

American Brake Shoe Company

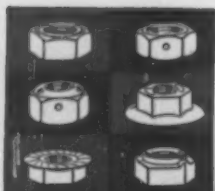
1240 Dublin Road • Columbus 16, Ohio

HYDRAULIC PRESSES
PUMPS • MOTORS • CONTROLS

DENISON

HYDRAULIC POWER

One

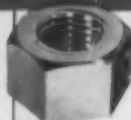


of these

CAN IMPROVE YOUR
PRODUCT...

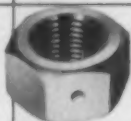
SIX GREAT MACLEAN-FOGG LOCK NUTS

MF UNI-TORQUE



A free starter with lock at the top.
Withstands severe vibrations.
Cuts assembly time.

MF TWO-WAY



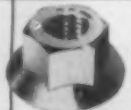
The Lock's in the center of nut.
Can be applied from either end.
Permits bolt end to be flush with,
or below, top of nut.

MF OPEN END CAP NUT



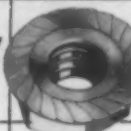
Has two-way center-of-nut lock.
Used on furniture, appliances,
toys, lawn mowers, tools, etc.

MF UNI-TORQUE FLANGE NUT



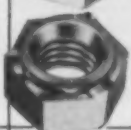
Combination lock nut and washer.
Use on oversized holes; where
extra bearing surface is needed.

MF "WHIZ-LOCK" FLANGE NUT



This one spins on. Serrations take
a firm grip on work. Break loose
torque higher than seated torque.

MF PILOT TYPE WELD NUT



You can have it with or without
lock. Simplifies assemblies by
means of self-locating pilot.

CIRCLE NUMBER FOR ILLUSTRATED CATALOG



MAC LEAN-FOGG

MacLean-Fogg Lock Nut Company
5535 N. WOLCOTT AVENUE
CHICAGO 40, ILLINOIS

WRITE OR
CALL FOR
ENGINEERING
HELP ON
FASTENING

NEW PARTS AND MATERIALS

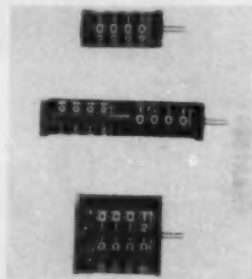
shoulders on which the cap rests and is self-centering in the groove, preventing cap from tipping in installation and operation and insuring a continuous, positive seal to 3000 psi with no spiral failure. Seal provides low break-out friction and minimum running friction in dynamic operation. Seal is for use without back-up rings and can be installed in standard MIL-P-5514D O-ring grooves. W. S. Shamban & Co., 11617 W. Jefferson Blvd., Culver City, Calif.

Circle 545 on Page 19

Mechanical Counters

for digital-readout
applications

Veederline high-speed, low-torque, direct mechanical counters are available for digital-readout applications where plus and minus, right and left, or directional readings are



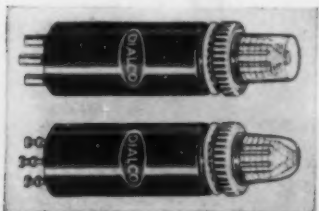
required. Counters have many military, commercial, and industrial applications. Line consists of 108 different units. Rigid single-piece, aluminum die-cast frame assures light weight, with Delrin wheels and pinions and stainless-steel shafts. Oilite bearings provide permanent lubrication, and open-frame construction allows for easy illumination. Counters have two to seven figures. Veeder-Root Inc., 70 Sargeant St., Hartford 2, Conn.

Circle 546 on Page 19

Neon Indicator Lights

subminiature units
are transistorized

Series STI neon indicator lights are completely enclosed, integrated units, with lampholder containing neon lamp, transistor driver, and required circuitry. Each unit is 1 15/16



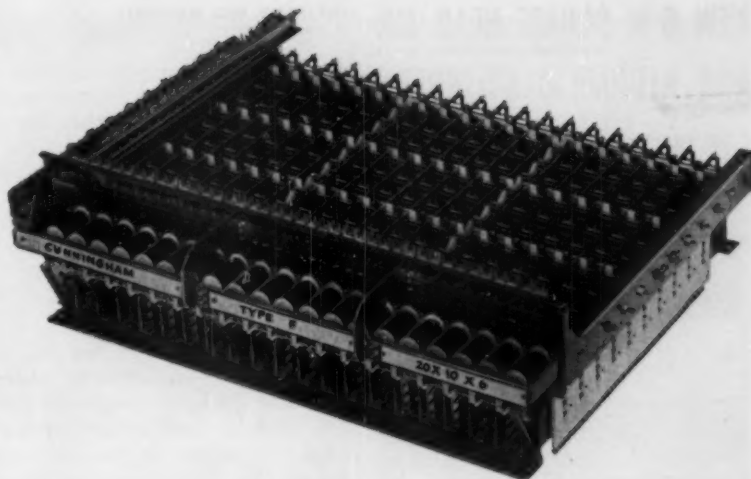
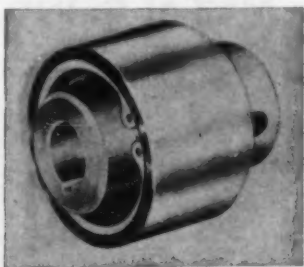
in. long and mounts in a single, $\frac{3}{8}$ -in. clearance hole from the back of the panel. Socket, lamp, and all connections are well insulated from the mounting bushing by phenolic material of military-specification grade. NE-2E or NE-2V neon lamps can be furnished aged, seasoned, and selected. Lenses of high-heat plastic are available in omnidirectional stovepipe or long cylindrical shape, with or without Fresnel diffusing rings, and in a choice of four colors. Series offers eight standard types of transistorized neon indicator lights which operate from input signals and supply voltages most commonly employed. Dialight Corp., 60 Stewart Ave., Brooklyn 37, N. Y.

Circle 547 on Page 19

Overload-Protector Coupling

runs in disengaged position without heat or binding

Torq-Tender frictionless overload-protector coupling is now available in five standard sizes. Smallest unit has 1-in. diam. with bore-through of 0.312-in. and torque range from $\frac{1}{4}$ to 24 lb-in.; largest size is 2.875-in. diam with bore-through of 1.125 in. and torque range from $1\frac{1}{2}$ to 75 lb-ft. Unit runs in disengaged position indefinitely without heating or binding. It gives positive, no-creep drive, disengages when torque setting is exceeded, and re-engages (below 25 rpm) automatically at same position on shaft every time. There are no timing problems. Input goes in either end of the unit;



Tolerance Buildup No Bugaboo with Punched Laminated Plastics Parts

The compounding of individual tolerances on several punched holes or cutouts over the length of the piece is not the bugaboo that many designers believe. Careful die work and good working knowledge of the laminate used minimizes tolerance buildup. A good example of what can be done is the insulated pusher fabricated by Taylor for a high-performance crossbar switch manufactured by James Cunningham, Son & Co., Inc., Rochester, N.Y.

These switches are 3-dimensional conductor matrices, with from 30 to 1200 switching contacts, which bring intelligence from as many as 600 sources to one or more readout or signal points. They are basic components in computers, machine tool programming systems, high frequency scanning systems, thermocouple and strain gage monitoring, and similar equipment.

The insulated pusher, only 2.955 in. long and .031 in. thick, and fabricated from Taylor Grade GEC-500 glass epoxy laminate, is a critical part of the crossbar. It must be held flat within $\pm .005$ in., with total over-length buildup not exceeding $\pm .002$ in.

The materials used before to fabricate the pusher proved difficult to hold to the tolerances required. The success of the GEC-500 laminate fabricated by Taylor is evidenced by marked reduction in rejects and a 20% gain in production.

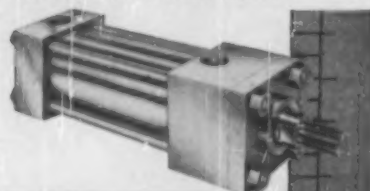
Taylor Fibre's Fabricating Division has the manpower, experience and equipment to produce parts to close tolerances from any of the company's raw materials. Send us your problem—we will recommend the best material for the job and quote on production runs. Write Taylor Fibre Co., Norristown 47, Pa.

Taylor

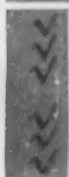
LAMINATED PLASTICS VULCANIZED FIBRE

NEW O-M SQUARE-HEAD AIR AND HYDRAULIC CYLINDERS

GIVE THE PERFORMANCE
YOU EXPECT... AND MORE



Air—(rated 200 psi)
Hydraulic—(rated up to 2000 psi)
Meet JIC Standards 1/4" to 1 1/2" Bore



Long Service
Uniform Performance
Dimensional Interchange-
ability
High Operational Efficiency
Compact—Saves Space
Quick, Easy Maintenance

Made of the highest quality materials and seals, these new components combine modern design, the latest and best engineering advancements with O-M specialized "know how" and precision workmanship.

New Series "K" Air Cylinders

Construction features include brass cylinder barrel, chrome-plated, high tensile steel piston rod with a minimum yield strength of 90,000 to 100,000 psi. Rolled and machined steel heads and extra long cartridge-type rod bearing assure perfect alignment of piston rod.

New Series "L" Hydraulic Cylinders

Similar in many construction features to Series "K", but specifically designed for hydraulic service. Incorporate vee-type rod packing and a cylinder barrel of micro-honed steel tubing which are best suited for hydraulic operations.

With the addition of the new Series "K" and "L" to the Ortman-Miller major line of air and hydraulic cylinders, you can now rely on O-M for all of your low and medium pressure cylinder requirements.

Mail coupon today for complete details. All cylinders in Bulletins 115A and 116 have been dimensioned in accordance with NFPA recommendations for your convenience.



ORTMAN-MILLER
MACHINE COMPANY
7 143rd Street, Hammond, Indiana

☐ Have representative call
Please send Bulletin(s)

☐ 115A—Series "K"

☐ 116—Series "L"

NAME _____

POSITION _____

COMPANY _____

ADDRESS _____

CITY _____

ZONE _____

STATE _____

Circle 314 on Page 19

NEW PARTS AND MATERIALS

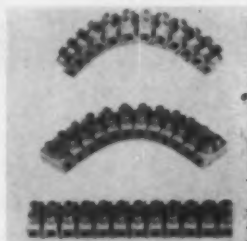
torque is applied in either direction. Helland Research & Engineering Inc., Box 56, Navarre Station, Wayzata, Minn.

Circle 548 on Page 19

Flexible Terminal Block

can be bent to fit
contours, sharp angles

Flexible terminal block No. 905 is available for applications where minimum space and weight are factors. Made of flexible polyester material, block can be bent in any direction to fit contours and sharp angles. Shortest distances between live parts is 3/8 in. Maximum wire size which terminals will accommo-



date is No. 10. Rating of the polyester material from which the block is fabricated is 25 amp. Block is 3 3/4 in. long, 5/8 in. wide, 1/2 in. high, and has 11/32 in. between terminal centers. Block can be cut to smaller sizes. National Tel-Tronics Corp., 52 St. Casimir Ave., Yonkers, N. Y.

Circle 549 on Page 19

Hose Clamp

for use where hose or fitting
is subjected to abrasion

Keystone Clamping Ring is a take-up-lug type hose clamp with the lug assuming a low-profile, key-stone-shaped head upon closure. Head makes the clamp adaptable to applications in close quarters and areas where a large protrusion would be undesirable. Where motion or vibration of hose assemblies is a factor, the wide band of the ring distributes clamping pressure over large areas and reduces the tendency of cutting or abrasion on hose surfaces. Unit is installed with an air or hand tool designed to provide take-up in the lug, while



Rodney
delivers

THIN STRIP
and FOIL

Precision Thinness
in Stainless and
Special Alloys...

Rodney concentrates its entire efforts, research and production, toward furnishing super thin, extra wide, precision rolled, metal strip and foil in all tempers and finishes. With the entire capacity of plant and personnel devoted exclusively to this specific area, Rodney can offer the added "know-how", manufacturing experience, quality control, and application knowledge your operation may require.

Rodney produces stainless steel strip... all alloys... in widths from 1/4" to 24"... at gauges from .012" to .0003". Rodney also rolls high temperature alloys and other special alloys on a production basis. Aluminum alloys, carbon steel strip and specialty custom rolling are also handled.

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Executive Offices:
261 Fifth Avenue, New York 16, N. Y.
West Coast Office & Warehouse:
2462 East Jilison St., Los Angeles 22, Calif.

Circle 315 on Page 19



at the same time compressing the metal into a compact head which resists opening. Multiple range of sizes of hoses can be accommodated for low and medium-pressure applications with the clamp designed to slip over the OD of the hose and be positioned ready for take-up. Cuyahoga Products Corp., 1600 N. Woodward, Birmingham, Mich.

Circle 550 on Page 19

Flocking Adhesive

is flame-resistant

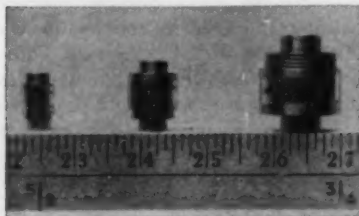
All-Flock flame-resistant adhesive will not support combustion even when placed in contact with direct flame. It can be used for applying glitter or sequins to a variety of materials. Material is noninflammable in its liquid state and can be sprayed, brushed, or applied by roller. It is available in 55-gal drums and in 1 and 5-gal containers. Allen Plastics Corp., 1015 E. 173rd St., New York 60, N. Y.

Circle 551 on Page 19

Slip Couplings

are designed for continuous slip

New couplings serve as torque limiters as well as couplings for two coaxial shafts. When load exceeds the limit torque of a slip coupling, the two shafts rotate relative to each other at full limit torque. Limit torque tolerance for the standard coupling is ± 15 per cent. Standard coupling operates with misalignments to 0.006 in. between the two shafts. Limit torques can have the same or different torques for the



November 23, 1961



SHOCK AND VIBRATION PROBLEMS?

SOLUTIONS . . . SUBMARINES TO SATELLITES

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Circle 316 on Page 19

205

if it concerns STAINLESS STEEL



and your
problems
are

or even
call **UNUSUAL
DIFFICULT
IMPOSSIBLE
A-P-C**

ALLOY PRODUCTS CORP.
1067 Perkins Avenue, Waukesha, Wis.

Circle 317 on Page 19

LOWELL REVERSIBLE RATCHET WRENCHES

designed to solve your problems

Speed of operation, simplicity of ratchet control, great strength... these are three big reasons why machinery designers write Lowell Reversible Ratchet Wrenches into their specifications.

- Remote or conventional reversing control.
- Handles any length up to 6 ft.
- Socket openings any size or shape.
- Engineered for quality performance.



WRITE TODAY FOR TECHNICAL DATA

LOWELL WRENCH CO.

93 Temple Street

Worcester 4, Massachusetts



This Niagara double crank gap frame press for long die area work uses a special built-in Lowell Series 20 Wrench for quick adjustment of the slide.

NEW PARTS AND MATERIALS

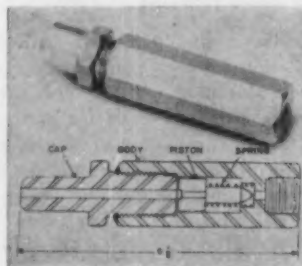
two directions of rotation. A 10:1 ratio of torques is available in standard units. Couplings are corrosion-resistant. **Machine Components Corp.**, 39 Fair Lane, Jericho, L. I., N. Y.

Circle 552 on Page 19

Check Valve

provide full closure
or a slow leak

Excess-flow check valve delivers positive, automatic protection against uncontrolled leakage. With only two moving parts, unit provides, according to a design option, either complete closure or a very slow calibrated leak. When flow-through exceeds predetermined rate,



a spring-loaded poppet valve shuts instantly. After the downstream rupture has been sealed, and the system has been recharged to normal pressure, valve resets automatically and normal flow is restored. **Chemiquip Co.**, 36 E. 10th St., New York 3, N. Y.

Circle 553 on Page 19

Wiring Raceway

has open-end
wire slots

Series VN Panel Channel wiring raceway permits wires to be inserted through the top of the channel wall, but prevents them from springing out of position before connections are made. Surfaces are rounded so wires can be inserted without damage to the insulation. Top access to the wire slots eliminates the need for threading wires through slots from inside the raceway channel, and makes it easier to handle wires with connectors attached. When panel wiring is revised, wires, with connectors at-



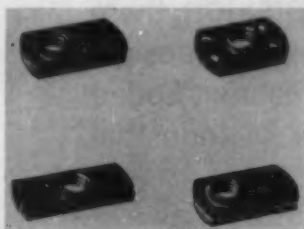
tached, can be lifted out of one slot and dropped into another with a minimum of disturbance to other wires in the raceway. Channel is molded of thermosetting plastic which is flame-retardant and does not warp. It is available in black, grey, or white in a full range of sizes. **Stahlin Brothers Inc.**, 500 Maple St., Belding, Mich.

Circle 554 on Page 19

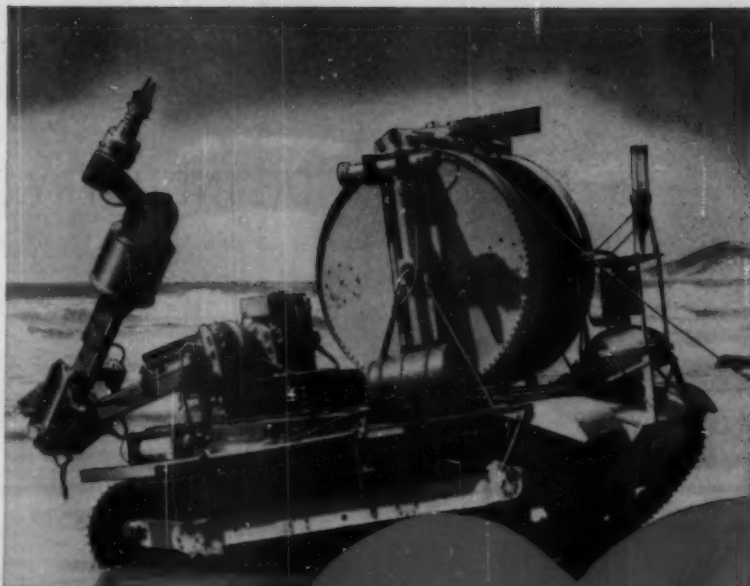
Tab Weld Nuts

of low-carbon steel
in two new types

Two new types of tab weld nuts are now available. Spotweld type is available in two configurations, S1 and S2. S1 nut has a self-locating pilot for fast feeding and welding. It has a single spotweld area at one end, with threads at the opposite end of the nut. It is designed for applications where space limitations are a factor, and allows for instantaneous welding. S2 type, which adds strength to the area to which the nut is welded, requires a double spotweld, with the threads located in the center of the nut. Both are low-carbon steel and produce a high quality weld. Pilot-projection type P1 has a single-weld projection, and the P2 has a four-weld projection. Both types add strength to the area to which they are welded. No re-tapping is required for either nut because of the location of the pilot



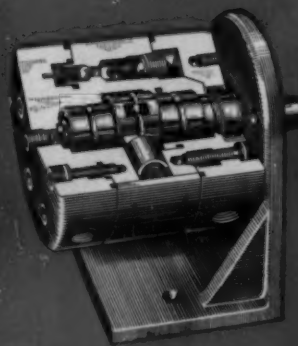
(Please turn to Page 210)



REMOTE UNDERWATER MANIPULATOR BUILT FOR THE U.S. NAVY BY THE SCRIPPS INSTITUTION OF OCEANOGRAPHY OF THE UNIVERSITY OF CALIFORNIA AND THE HUDSON LABORATORIES OF COLUMBIA UNIVERSITY.

**This hardy
HYDRAULIC
HEART operates
efficiently even
20,000 ft.
under water**

A RACINE pump actuates the mechanical arm on the Remote Underwater Manipulator, a new experimental vehicle the U.S. Navy uses to explore the ocean floor down to depths of 20,000 ft. The arm makes all the motions of the human arm and hand. It picks up samples from the ocean floor . . . assembles and installs instruments in the ocean depth. Land-based remote controls operate the underwater explorer. Rated at 1,000 psi continuous pressure, the RACINE pump automatically compensates for the compressibility of oil under various sea water pressures. When you need versatile hydraulic components — sturdy and dependable for any use from research to assembly line — your best choice is RACINE!



*The Heart of this
Exotic Ocean Explorer
Is a RACINE
MODEL D6 PUMP*



Racine Hydraulics & Machinery, Inc.
RACINE, WISCONSIN
HYDRAULICS DIVISION



AT THE HEART OF INDUSTRY...



Helping to create a revolution in wire-drawing, heavy-duty U.S. PowerGrip "Timing"® Belts are now used exclusively on machines made by the Whitacre Corporation of Los Angeles. Their positive, compact, maintenance-free driving power has enabled Whitacre to not only increase efficiency greatly, but to lower cost of the equipment at the same time. These belts are still operating after years of 24-hour-a-day service.

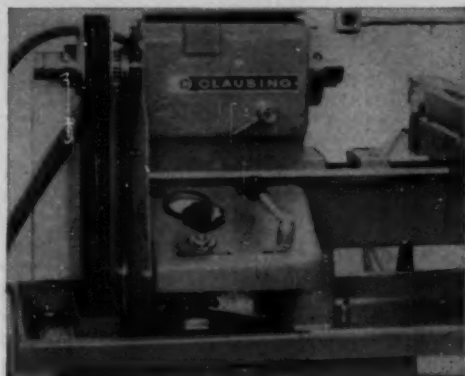
TB 101

Wherever there is need for better power transmission, there is need for US Industrial Rubber Products. They help simplify design, contribute to efficiency and add to the profit of the manufacturer. Sound reasons for looking to US, the world's largest producer of industrial rubber products.



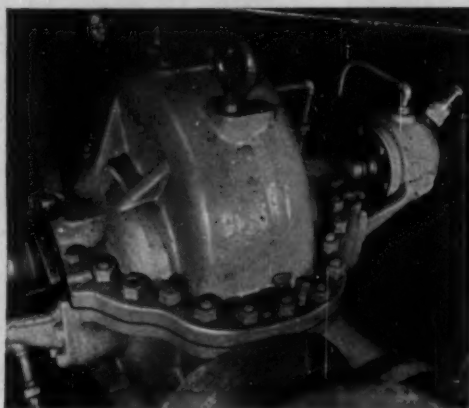
Eliminating pile-ups and product waste for American Can. U.S. SteepGrade Conveyor Belts carry light, smooth-finished cartons down a 45° incline. An exclusive, molded gripper cleat construction gives safe, positive control even at extreme angles that require an absolute minimum of floor space. Uphill, down, or cross country, there's an experience-engineered US Conveyor Belt for every moving need.

CB 102



The abuse of continual starting and stopping was no problem for the U.S. Royal V-Belts used on this Clausing semi-automatic boring and turning lathe. These belts were selected because they ran cool, took little space, were exceptionally high in power-transmission efficiency. They proved to be the most uniform and smoothest running of many belts tested.

VB 125



Reducing friction and wear on rods and shafts, exceptionally high-quality US Centrifugal Pump Packings resist hot, cold, and salt water; seal against oil, brine, weak acids, caustic solutions, and ammonia. These braided asbestos packings are used as standard equipment by many leading centrifugal pump manufacturers.

P 105

For every industrial rubber product need, turn to US. For Conveyor Belts, V-Belts, the original PowerGrip "Timing"® Belt, Flexible Couplings, Mountings, Fenders, Hose and Packings... custom-designed rubber products of every de-

scription. Discover why U.S. Rubber has become the largest developer and producer of industrial rubber products in the world. See your U.S. Rubber Distributor or contact US directly at Rockefeller Center, New York 20, N. Y.

WORLD'S LARGEST MANUFACTURER
OF INDUSTRIAL RUBBER PRODUCTS



United States Rubber

MECHANICAL GOODS DIVISION

Circle 320 on Page 19

Compare Index Units! FERGUSON "PROVES OUT" ... Point by Point.

Selection of components for a production machine should be based upon the machine's return per dollar investment. Matching "first costs" only does not generally result in the design of profitably operated equipment.

Here is a check list for comparison of indexing mechanisms. "Price" is shown in its order of consideration.

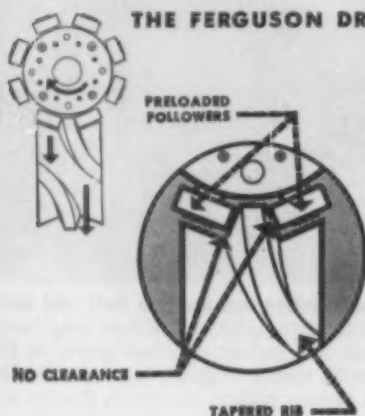
1. BACKLASH—None? Some during the dwell or index or both? Any backlash during any part of the cycle results in wear-causing vibrations and shock loads... *The Ferguson Drive maintains zero backlash at all times.*

2. RATED LOADS—What is the rated life and under what load? What is the average follower life (B-10 life)? The Ferguson Drive is rated at maximum precision for at least 8,000 hours operation and with an average follower life of 90%. Replacement of the followers renews the life of the Drive for another 8,000 hours. Ferguson cams never wear out under rated loads.

3. JOB SUITABILITY—Can the acceleration characteristic be pre-selected according to job requirements or is it inherent in the mechanism or limited by the manufacturer? Acceleration of the Ferguson Drive can be chosen after an application evaluation to provide optimum operation.

4. INDEXING ACCURACY—Are time-consuming shot pins necessary for precision?... They soon wear and lose accuracy. The Ferguson Drive is positive locking and locating for extreme precision without shot pins.

5. FIRST COST vs. TOTAL COST—Now consider the higher production rates, better quality and much lower maintenance costs the Ferguson Drive gives you. Determine the *total cost* of the various indexing mechanisms. The Ferguson Drive has proved out... And you're on the way to building more profitable production equipment.



Cam features a tapered rib along which two standard cylindrical followers roll without clearance... maintaining zero backlash during index and dwell. While in the dwell or "work" position a straight portion of the cam rib locks the hub positively, without auxiliary locating or locking devices. *Extreme precision is inherent, even at speeds as high as 2,000 indexes a minute!*

CATALOG NO. 161 gives complete design data on nearly 100 standard indexing mechanisms, over 150 index

tables and various auxiliary items. Send for your free copy... There's one for every design engineer.



FERGUSON MACHINE COMPANY

A Division of Universal Match Corporation
7818 Maplewood Court • St. Louis 17, Missouri

NEW PARTS AND MATERIALS

(Continued from Page 207)

and projections. Both can be welded to a variety of metal thicknesses and weld settings. Grip Nut Co., South Whitley, Ind.

Circle 555 on Page 19

Appliance Switch

needs only 1/2-in.
mounting clearance

Series SS-37 slide switch is a 6-amp unit for household appliances, power tools, and other electrical equipment. Switch is 1 5/8 in. long, 1/2 in. wide, and 1/2 in. deep, excluding trigger. Mounting clearance is only 1/2 in. so that the switch can be used in tight locations. Switch consists of a nickel-plated steel case per-



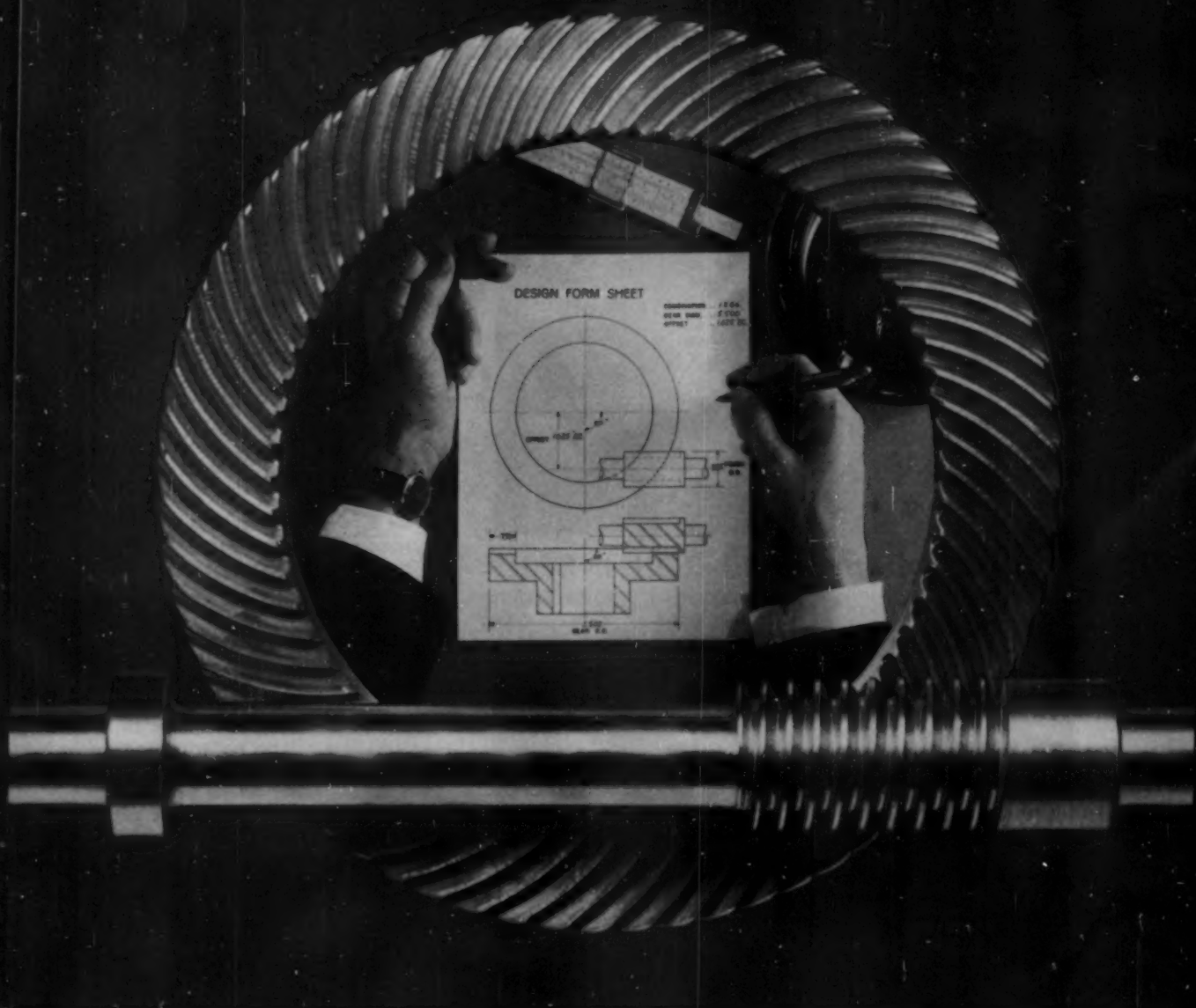
manently attached to a molded-nylon base. Terminals are recessed within the nylon base in individual barrier channels which lengthen creepage paths and prevent accidental contact between terminals. Optional nylon terminal cover is available for applications requiring complete electrical safeguards. Terminals are silver-plated and adaptable to either soldered or solderless connections. Molded phenolic actuating triggers are available in 11 standard colors and in heights of 7/32, 11/32, and 19/32 in. Electronic Components Div., Stackpole Carbon Co., St. Marys, Pa.

Circle 556 on Page 19

Miniature Motors

Size 11 units have watt
input as low as 1.5 w

Compact, high-performance hysteresis, synchronous, and induction miniature motors are aluminum and stainless steel throughout. Watt input is as low as 1/5 w. Total indicator readings on shaft run-out do not exceed 0.0001 in. Units are available for 12, 24, 26, 48, 115 and



Why it will pay to design your high reduction gearing with Gleason HRH*

If you want to make your transmission more quiet or more compact or more flexible, take a good long look at the HRH set shown above.

This single set of gears gives a reduction of 66 to 1.

The action is quiet and smooth and continuous because the pinion teeth *wrap around* the gear teeth. With this design you can work such quiet operation into your designs even with a one- or two-tooth pinion member.

You can add the rigid support of a straddle mounting, since bearings can be put on both ends of the pinion.

HRH gear ratios are made with proven face mill cutting techniques, assuring complete control of tooth contact pattern to compensate for any assembly or operating condition.

HRH gear ratios are designed with the *full* assistance of all

Gleason engineering services. We work with you on the practical design aspects and carry through to the development of prototypes. Then we furnish both machines and tooling for full production—*without royalties*.

Find out what HRH gearing can do for your transmissions. Send for our design form sheet and then send us the gear ratios and sizes you want. We'll send back detailed recommendations promptly.

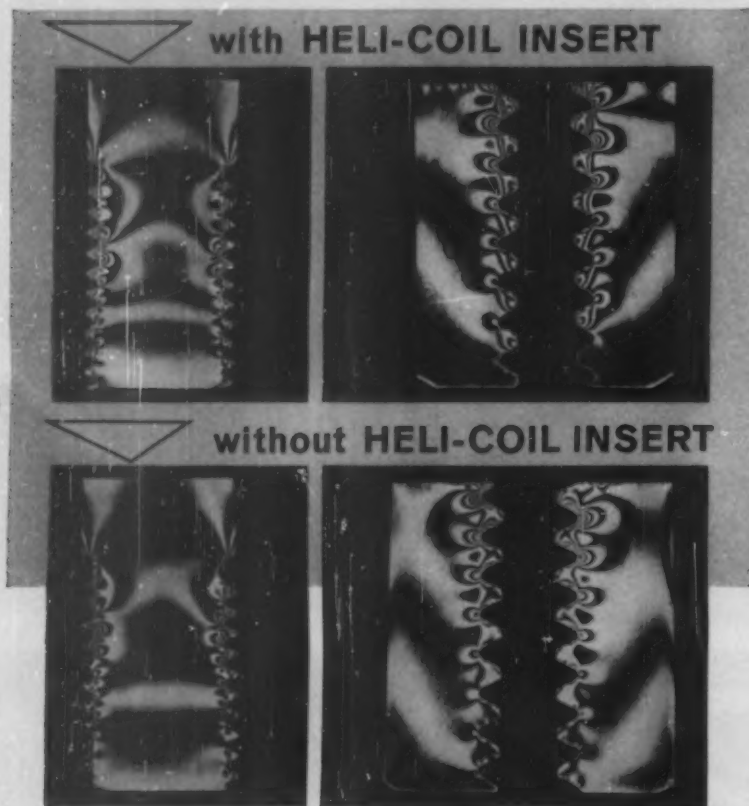
*Trademark for Gleason High Reduction Hypoids



GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N. Y.

How HELI-COIL® Stainless Steel Wire Inserts Eliminate Stress Concentration and Insure Maximum Strength in Threaded Assemblies



Made of stainless steel wire, precision-rolled to a diamond-shaped cross-section, *Heli-Coil* screw thread Inserts provide two exclusive characteristics directly related to threaded assembly strength:

1. **Permanent, resilient threads between the threads of the male and female assembly members.** These eliminate stress concentrations (upper photos) by distributing the load evenly along the full length of thread engagement in both members. By contrast, note the sharp stress concentrations (lower photos) around the first two threads of the conventional assembly.

NOTE: Diagrams at right show how *Heli-Coil* Inserts compensate for lead and angle error between female and male threads.

2. **A superior surface finish (8-15 RMS).** This holds friction loss to a minimum and, thus, provides maximum, consistent clamping load at any given wrench torque load.

RESULT: No stress concentration; improved fatigue strength in the male member; and a stronger assembly under all conditions.

There is a complete line of *Heli-Coil* products for every thread need: inserts, taps, tools and gages. Let us help with your design and application problems. Write today for complete information.

3146



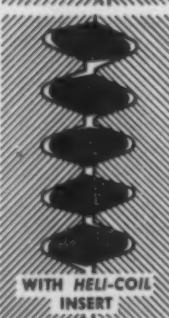
HELI-COIL CORPORATION
511 Shelter Rock Lane, Danbury, Conn.

In Canada: ARMSTRONG BEVERLEY ENGINEERING LTD., 6975 Jeanne Mance St., Montreal 15, Que.

SCREW THREAD ENGAGEMENT



CONVENTIONAL



WITH HELI-COIL INSERT

NEW PARTS AND MATERIALS



higher voltage operations, in one, two and three phase. Variety of extra features is also available. Martronic Inc., 82 Sanford St., Hamden 14, Conn.

Circle 557 on Page 19

Nonclogging Nozzles

of one-piece construction

Series NC nonclogging, full-cone nozzles are for use wherever high-capacity, center-jet nozzles are used. Whirling action is obtained by vanes cast integrally with the shell with large internal openings and straight-through flow at the center. One-piece units are available in sizes from 1 to 8-in. female pipe thread, with capacities from 10 to 3000 gpm. Spray patterns are uniform full cones of 50 to 90 deg. Standard materials are bronze and cast iron; other materials are avail-



able on special order. Betefog Nozzle Inc., 309 Wells St., Greenfield, Mass.

Circle 558 on Page 19

Plastic-Covered Handles

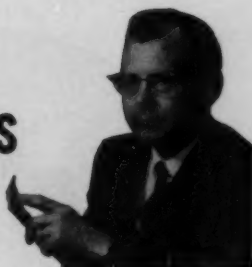
with 1 1/4, 2, or 3-in. widths between centers

New handles are brass, with molded-vinyl covering which serves as an electrical insulator and, in cold climates, eliminates the problem of hands sticking to bare metal. Standard color of the molded vinyl is black; other colors are also available on special order. Handles, identified as Parts 1240-1, 1240-2, and 1240-3, include a choice of three different widths between centers—

A design engineer tells...

How we design General Electric Heaters to meet your rigid quality specs

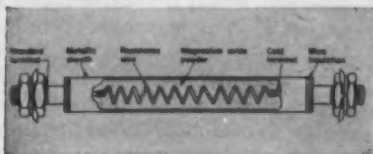
T. Skogland, Supervisor, Production Engineering, Industrial Heating Dept., General Electric Co.



The approach to heater design is basically one of matching long life with optimum cost. Does the application require a few minutes ultra-dependable operation on a missile, or many thousands of hours in typical industrial use? Then these four points must also be closely considered: 1) environment—including temperature, chemical content, and physical abuse; 2) heat output; 3) size; and 4) special application requirements.

LONG LIFE FIRST OF ALL

In our Calrod® tubular heaters, for example, we know we have a basic design which gives long, dependable life. The cutaway shows construction features which make these heaters resist physical abuse. For instance, the heating element is encased in rock-hard magnesium oxide insulation and a strong metallic sheath.



General Electric tubular heaters are designed for maximum durability.

The choice of sheath material depends on the environment. For water we usually recommend a copper sheath; for cast-in and low-temperature applications, a steel sheath; higher temperatures normally require a stainless steel or other alloy sheath for greater oxidation-resistance.

Where corrosive liquids will be encountered, we recommend corrosion-resistant sheath materials. These might be steel, stainless steel, a special alloy, or lead.

THE HEART OF THE HEATER

Inside the sheath there are other decisions to be made. We select our resistance wires to match the internal heater temperature ranges for the application. Some of the wires used are 80 Nickel, 20 Chrome; 60 Nickel, 16 Chrome; and the Aluminum Chrome Ferrous types. And for insulating material we use magnesium oxide powder with its high dielectric strength and excellent thermal conductivity.

Once the right amount of heat is specified, we then want to be sure heat distribution is uniform along the entire effective heating length of the heater. Our

machines for winding and stretching the helical resistance coils are specially designed to provide consistently uniform heat distribution.

SPECIAL SHAPES AND ACCESSORIES

Special applications often require special shapes. To meet your needs, General Electric tubular heaters can be bent into virtually any configuration. One limitation is that the bending radius cannot be less than the sheath diameter. Again, special equipment and highly trained personnel enable us to produce formed heaters consistent in size and shape. The example of a formed heater you see here appears extreme, but we've formed many which are even more complex.

Accessories are often required to permit easy heater installation. Usually you can choose from our time-tested selection of terminals, seals, bushings, etc. However, there are times when a standard won't quite do the job for you. Our experience helps us design and manufacture custom-made accessories to meet your specifications.

For instance, we have standard terminations from staked-on threaded stud type to side-projection-welded screw type. And this selection includes quick-connect types. The variety of other terminals we can design for you is almost limitless.

When the heater is applied in liquids or a gaseous atmosphere, sealed terminations become important to the design. The selection will depend on the operating temperature, and whether a true hermetic seal or merely moisture retardation is required. Some of the terminations we use are molded rubber, plastic resin, silicone, and ceramic-to-metal.

MUST PERFORM WELL, LOOK WELL

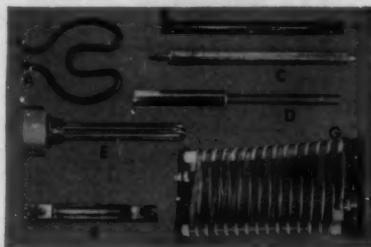
We feel that a heater should both perform well and look well. Our mechanical,

electrical and visual inspections provide you with just that. There are tests for wattage, insulation resistance, appearance, and key physical features. These tests performed according to rigid pre-planned quality control standards, are an integral part of our production line.

When we have made sure that your heater is designed to meet your specifications and can be manufactured, the next logical subjects are price and delivery. These are especially important for your purchasing group. Whenever I've discussed price and delivery with our sales and application engineers they've been very emphatic in their assurances that they can meet any reasonable delivery requirement, and quote competitive prices.

As a design engineer, my own feelings about component prices are these: *When a component represents a major part of a product's total reliability but only a minor part of the total cost, I will argue for any reasonable price differential to make sure the best component is purchased. I want my product to be reliable.*

If you are designing heat into your product or process, we can help you select the right heater for your specific need. Please send complete details to Section 757-07, General Electric Co., Schenectady 5, N. Y. or your local G-E sales office. I will work closely with our sales and application engineers to develop the right heater to meet your specifications.



High reliability is designed into all G-E Calrod heaters: tubular (A); vane (B); finned tubular (C); cartridge (D); immersion (E); strip (F); and oven (G) heaters.

Progress Is Our Most Important Product

GENERAL  ELECTRIC



**IT ALL
ADDS UP
TO THIS...**

**YOU CAN'T BUY
SURE-FLEX
PERFORMANCE
IN ANY OTHER
COUPLING AT
TWICE THE PRICE**

Wood's Sure-Flex Couplings not only have full, 4-way flexing action, but absorb from 5 to 15 times more shock and vibration than other leading flexible couplings. They swallow all types and combinations of angular and parallel misalignment and end float. Sure-Flex couplings are simple, easy to install. Standard models have only 4 basic parts . . . no bolts, nuts, screws, clamps or covers. And, they last endlessly (6 1/4 million 15° peak torque flexes with no sign of wear). There's no metal-to-metal contact, no wear, no need for lubrication. Available in capacities up to 500 hp at unity service factor . . . in standard, junior, bushed and spacer types. There's a lot more to tell about Sure-Flex.



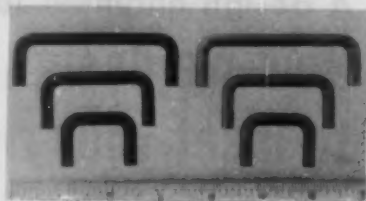
Write for BULLETIN 5103.

T. B. WOOD'S SONS COMPANY • CHAMBERSBURG, PENNSYLVANIA

SF/2361

ATLANTA • CAMBRIDGE • CHICAGO • CLEVELAND • DALLAS

NEW PARTS AND MATERIALS



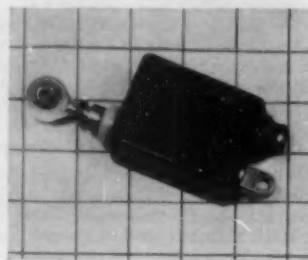
1 1/4, 2, and 3 in. All models are tapped for No. 4-40 screw and have standard 1-in. height and 5/32-in. OD. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge 38, Mass.

Circle 359 on Page 19

Rotary Actuators

miniature units have
low power consumption

Two new miniature rotary actuators provide maximum performance and reliability in applications where small size and light weight are important. Actuators have low power consumption and high positioning accuracy. Model R-1724, weighing 8 oz, has 25 lb-in. maximum operating load, speed range from 0.5 to 50 rpm, and operating life of 10,000 cycles for intermittent or continuous duty. Model R-2329 weighs 1 lb, has a maximum operating load of 50 lb-in. and a speed range from 0.3 to 60 rpm. Rotation can be



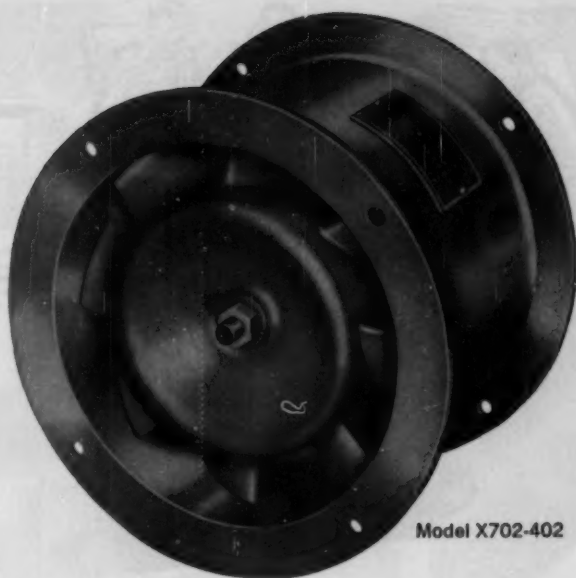
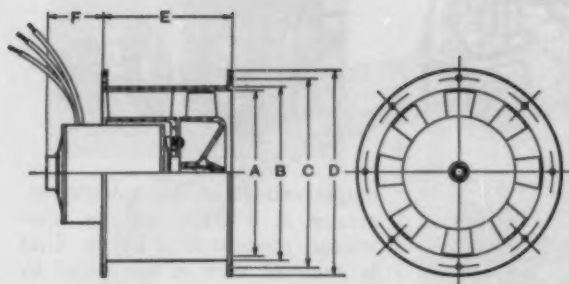
controlled to ± 1 deg, with higher accuracy available. Nash Controls Inc., 69 Summit St., Newark 4, N. J.

Circle 560 on Page 19

Variable Transformer

is rated at 10 amp
and 1.4 kva

Model T101U square-base, high-output, Adjust-A Volt variable transformer is rated at 10 amp and 1.4 kva. Input voltage is 120 v, and



Model X702-402

A Complete New Line of Electronic Cooling Fans JOY Axivane Series 60

Developed by Joy specifically for 60 cycle commercial duty, the Series 60 vaneaxial fans operate at 3400 rpm, 115 volts, single phase, 50/60 cycles and produce from 50 to 500 cfm at static pressures of $\frac{1}{4}$ " through 1" wg. They are extremely compact and ruggedly built

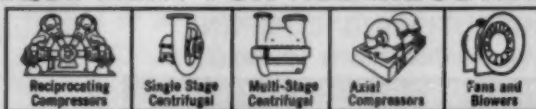
of anodized aluminum. There are only four major parts; rotor, housing, motor, and separately mounted capacitor. Production quantities are available on order and small quantities are available off-the-shelf. For more information write for bulletin 3313-64B.

Part No.	Design CFM $\pm 3\%$	Max. CFM at Free Flow	Design PS $\pm 7\%$	Max. Total Pressure	Motor Data			Mechanical Dimensions (Inches)						$\frac{1}{32}$ " Holes Per Flange	Total Weight Pounds
					BHP	Full Load Amps	CAP* MFD	A	B	C	D	E	F		
X702-401	50	62	0.30	0.50	.005	0.67	None	4.37	4.62	5.25	5.87	4.50	0.9	4	5.4
X702-402	100	135	0.42	0.55	.010	0.67	None	5.12	5.37	6.00	6.62	4.50	0.9	4	5.8
X702-403	150	172	0.35	0.45	.015	0.67	None	5.62	5.87	6.50	7.12	4.50	0.9	4	6.1
X702-404	200	250	0.50	0.85	.035	0.95	5	5.62	5.87	6.50	7.12	5.00	1.3	8	7.2
X702-405	250	280	0.35	0.82	.043	0.95	5	5.87	6.12	6.75	7.37	5.00	1.3	8	7.4
X702-406	300	340	0.35	0.88	.052	0.95	5	6.12	6.37	7.00	7.62	5.00	1.3	8	7.6
X702-407	350	440	0.50	1.00	.060	1.45	5	6.37	6.62	7.25	7.87	5.00	1.5	8	8.5
X702-408	400	520	0.75	1.00	.068	1.45	5	6.62	6.87	7.50	8.12	5.00	1.5	8	8.7
X702-409	450	580	0.75	1.05	.075	1.45	5	6.87	7.12	7.75	8.37	5.00	1.5	8	8.9
X702-410	500	625	0.75	1.05	.083	1.45	5	7.12	7.37	8.00	8.62	5.00	1.5	8	9.1

*Rated 236 WVAC **At peak of curve

Note: Spun aluminum inlet bells and aluminum wire inlet bell screens are available to fit all sizes of fans.

AIR MOVING EQUIPMENT FOR ALL INDUSTRY



JOY

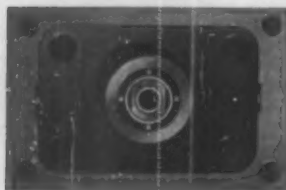
Joy Manufacturing Company
Oliver Building, Pittsburgh 22, Pa.

In Canada: Joy Manufacturing Company
(Canada) Limited, Galt, Ontario



Pathon has Something for Everybody

Pathon Cylinders are designed to give you a highly practical cylinder that fits into almost every situation where a hydraulic cylinder is needed. Maintenance is at an absolute minimum because Pathon Cylinders are simple and easier to take apart and put together.

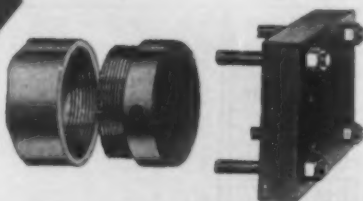


For the User

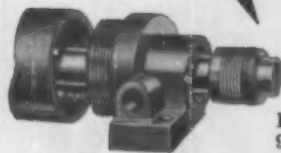
Pathon's screw thread head design gives you up to 40% more strength than most tie-rod cylinders. This increased strength means less maintenance, longer life.

For the Designer

Pathon's compact design saves valuable space, makes your designing job easier, and gives your equipment added dependability with a modern, rugged appearance.



For the Maintenance Man



Rod packing and bearing is externally replaceable and any part can be replaced without complete disassembly and the resulting "basket full of parts."

Pathon Hydraulic Cylinders are available in 9 mounting types, thirteen bore sizes—1½", etc., through 14", and three Series—for 1000 PSI, and 2000 PSI and 3000 PSI.

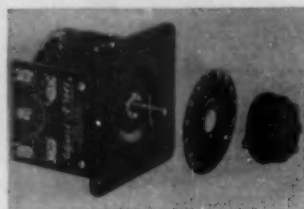
Write for Bulletin No. 22-A

Pathon MANUFACTURING COMPANY

3823 PACIFIC AVE. • CINCINNATI 12, OHIO

FLUID OPERATED AND CONTROL EQUIPMENT

NEW PARTS AND MATERIALS



output voltage on line-voltage connection is 0-120 v and by over-voltage connection, 0-140 v. Unit is mounted back of the panel by using either mounting holes provided in each corner of the base or by using threaded holes in the die-cast aluminum base. Design provides optimum heat transfer from winding to base for efficient cooling. Shaft is adaptable for either back-of-panel mounting on different panel thicknesses or for bench mounting. Two and three-gang assemblies are also available. Standard Electrical Products Co., 2240 E. Third St., Dayton, Ohio.

Circle 561 on Page 19

Packing Lubricants

for temperatures to 500 F

Luball, with molybdenum disulfide, and Compound 2 are two new lubricants developed to improve the performance of packings. Pastes are available for use against water, steam, and chemicals at temperatures to 500 F. Both are available in a variety of weights. Garlock Inc., Palmyra, N. Y.

Circle 562 on Page 19

Flexible-Shaft Coupling

with maximum torque capacity of 470 lb-in.

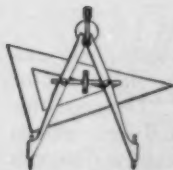
Waterproof flexible-shaft coupling is available for applications where moisture is a problem, such as pump drives. The ¾-in. diam core is made of layers of high-carbon wire, and is covered with 1-in. OD by ¾-in. ID transparent vinyl-plastic



SIZE RANGE *Unlimited...*



MESSINGER BALL AND ROLLER BEARINGS... Standard sizes from 2" I.D. "Featherweight", to the world's largest... 160½" O.D. "X" Type. And the application range is just as broad... from small instruments and appliances to huge radar screens for the Nation's warning systems. Regardless of size, their use assures reliable product performance throughout exceptionally long service life.



Let Messinger Engineers help you determine the right bearing for the product you are designing. Consultation without obligation.

MESSINGER  **BEARINGS, Inc.**

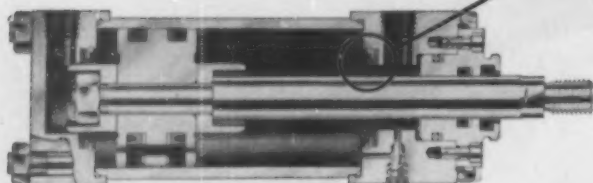
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"Smoothing Industry's Pathway for Nearly Half a Century"

WILBOW precision seals improve power cylinder action



Check seal cushions by WILBOW provide effective cushioning of HANNA-POWER** AIR Cylinders.



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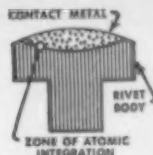
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The WILLIAMS-BOWMAN RUBBER CO.

1951 South 54th Avenue • Cicero 58, Illinois • (Chicago Suburb)
Mfrs. of molded, punched, extruded and cut rubber goods. Specialists in producing rubber covered rolls, silicone rubber parts and bonding rubber to metal

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

Gibson Atomiclad* Electrical Contact Rivets now available in economical Gibson Assemblies ATOMICLAD RIVETS ARE LOWER COST BECAUSE IT COSTS LESS TO MAKE THEM



Patents Pending

ECONOMICAL GIBSON CONTACT ASSEMBLIES

Gibson contact support manufacturing facilities include every phase—forming, riveting, heat-treatment and electroplating and comprises use of any specified metal.

When you specify Gibson Contact Assemblies, you get the benefit of years of engineering know-how in providing the best possible electrical union between contact and support member. Since all assemblies are Gibson-inspected, the customer suffers no loss through assembly rejects.

Gibson Engineers will design your complete contact assembly upon receipt of specifications. Or send your drawings for fabrication costs. If you prefer your own support member, send a sample for assembly cost.

*ATOMICLAD—Trademark Gibson Electric Company

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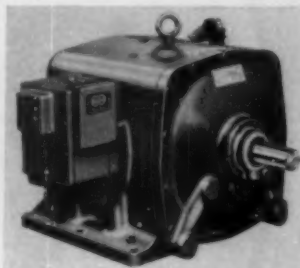
NEW PARTS AND MATERIALS

casing. End fittings are stainless steel to prevent corrosion. Maximum torque capacity is 470 lb-in. Unit can be bent into a 15-in. radius of curvature, making it suitable as a connection between two shafts that are not lined up perfectly or have some relative motion. Stow Mfg. Co. 11 Shear St., Binghamton, N. Y.

Circle 563 on Page 19

Variable-Displacement Pumps

deliver 5 to 108 gpm
at 1100 to 3000 psi



Type DV heavy-duty, two-way, variable-displacement pumps have electrohydraulic servo-operated controls. Any number of variable low-level electrical input signals from remote positions can vary the rate of pump flow from either directional port. Single-stage servo-control valve directs low-pressure fluid to or from stroker to vary pump displacement from zero to maximum in 0.15 sec on small units and 0.25 sec on large units. Pumps range in size from 13 to 169 gpm for pressures to 1350 psi and from 5 to 108 gpm for pressures to 2050 and 3000 psi. They are designed with integral control, built-in gear pump, high-pressure relief, gear-pump relief, and suction valves. Oilgear Co., 1570Q W. Pierce St., Milwaukee 4, Wis.

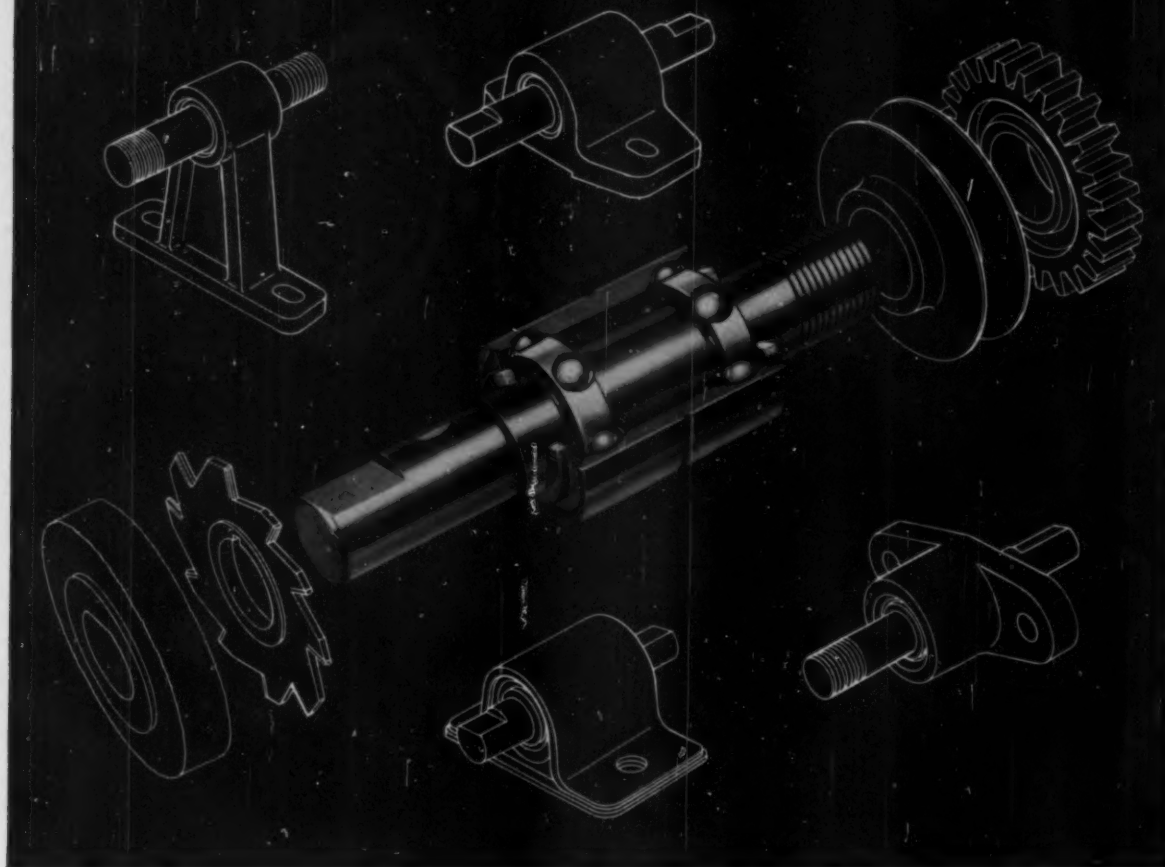
Circle 564 on Page 19

Split-Phase Motors

for belt-drive
blowers and fans

New 1/2 and 3/4-hp, split-phase motors are available in either 115 or 115/230-v models. Designed for belt-drive blowers and fans, motors have low starting torque and smooth acceleration. They start at less than full-load torque and smoothly ac-

VERSATILE!



HOOVER INTEGRAL SHAFT BEARINGS IN UNLIMITED MODIFICATIONS CAN SOLVE YOUR DESIGN PROBLEMS AT LOW COST

In practically every application where bearings are applied to a shaft, Hoover Integral Shaft Bearings can cut costs and improve product efficiency. These compact, self-contained units cost less than separate components and save time during product assembly. Widely spaced rows of balls or rollers provide shaft stability and smooth operation.

Hoover *Micro-Velvet* Balls fitted into raceways *Hoover Honed* directly on the shaft assure quiet operation, high load capacity and long life. Hoover Integral Shaft Bearings are available in a wide variety of bearing units, shaft types, seals and combinations. For information, mail the coupon below.

Micro-Velvet and *Hoover Honed* are Hoover Trademarks

Hoover

BALL AND BEARING COMPANY

3400 South State Road, Ann Arbor, Michigan

Zone Sales Offices and Warehouses | 8581 South Chicago Ave., Chicago 17, Illinois
290 Lodi Street, Hackensack, New Jersey
2020 South Figueroa, Los Angeles 7, California

Hoover Ball and Bearing Company
3400 South State Road, Ann Arbor, Michigan

MB-11

Please send me information on Hoover Integral Shaft Bearings.

Name _____

Title _____

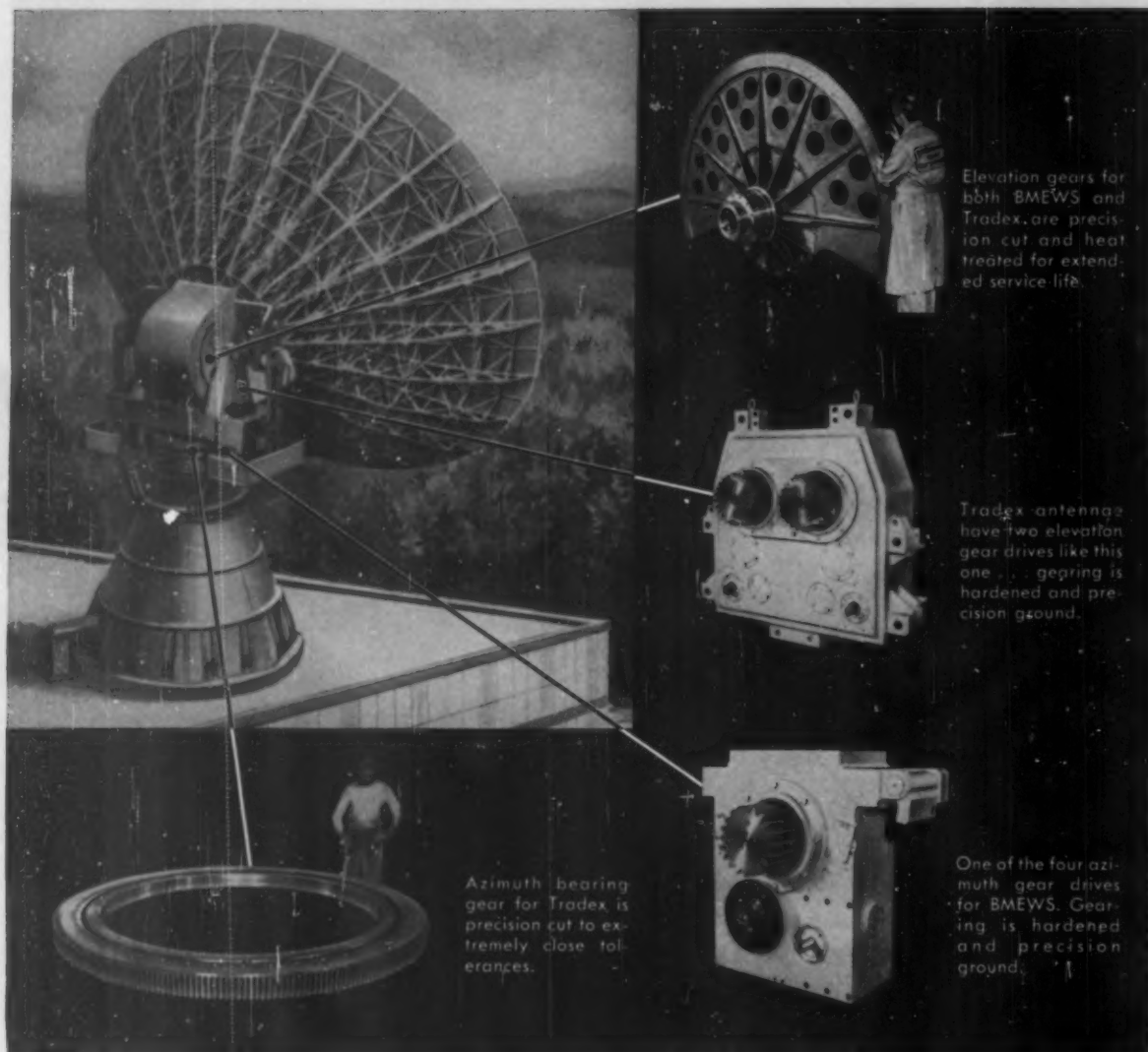
Company _____

Address _____

City _____ Zone _____ State _____

PHILADELPHIA GEARS AND DRIVES

power BMEWS and TRADEX antennae



Elevation gears for both BMEWS and Tradex are precision cut and heat treated for extended service life.

Tradex antennae have two elevation gear drives like this one . . . gearing is hardened and precision ground.

Azimuth bearing gear for Tradex is precision cut to extremely close tolerances.

One of the four azimuth gear drives for BMEWS. Gearing is hardened and precision ground.

When the giant radar tracking antennae for our ballistic missile early warning systems zero in on a 16,000 mph missile . . . and then hold it in dead center focus . . . there can be little margin for error.

The delicately sensitive, ultra precision movement of most of these big scanning dishes depends upon Philadelphia gearing and gear boxes.

Azimuth and elevation gearing is precision cut to extremely close tolerances. For installations involving severe loading cycles, the gearing is induction hardened to assure depend-

able long life and to maintain accuracy of teeth over an extended life period.

Rugged gear boxes are proportioned to critical stiffness requirements and gearing is precision ground throughout to assure minimum backlash and uniformity of performance from box to box. An added benefit is assured reliability over designed life expectancy.

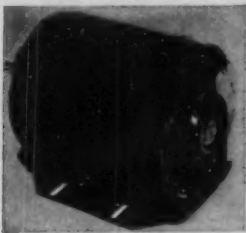
Need a better solution to your gear and drive problems? Then write for our catalog, "An Advanced Concept in Modern Gears".



PHILADELPHIA GEAR DRIVES

PHILADELPHIA GEAR CORPORATION • King of Prussia (Suburban Philadelphia), Pa.





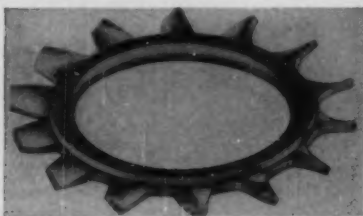
celerate the blower to full performance. Motors cause less belt wear and have reduced starting noise. Industrial Motor Dept., Westinghouse Electric Corp., P. O. Box 566, Lima, Ohio.

Circle 565 on Page 19

Lock Washers

in sizes from
No. 10 to $\frac{5}{8}$ in.

New No. 10 and $\frac{1}{4}$ -in. sizes have been added to a line of folded-rim lock washers. Sizes now range from No. 10 to $\frac{5}{8}$ in. Folded-rim lock washer is a modification of standard external lock washer with a folded internal rim that provides additional body strength to resist fastening stresses when working with steel, die castings, or other metals requiring high torques. It is useful in applications involving high-pressure sealing, since the



folded rim eliminates thread leakage. Shakeproof Div., Illinois Tool Works Inc., St. Charles Rd., Elgin, Ill.

Circle 566 on Page 19

Adjustable Stop Switches

are extremely flexible in use

Line of 87 adjustable stop switches replaces in performance 2001 standard catalog types. Replacing standard switches with a fixed number of positions, adjustable stop switches permit an increase or decrease of positions as circuit requirements

(Please turn to Page 224)

November 23, 1961

look to the man
from Louis Allis
for Dynapar digital
control and instrumentation
that's accurate to the
nth degree!

Dynapar is the electronic subsidiary of The Louis Allis Co., Milwaukee 1, Wis. We make a full line of transistorized digital counting, measuring, and control devices. Information on any of these products can be obtained from your local Louis Allis District Office — which is listed in The Yellow Pages under "Electric Motors."



Draw
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Rotopulsers

80-222

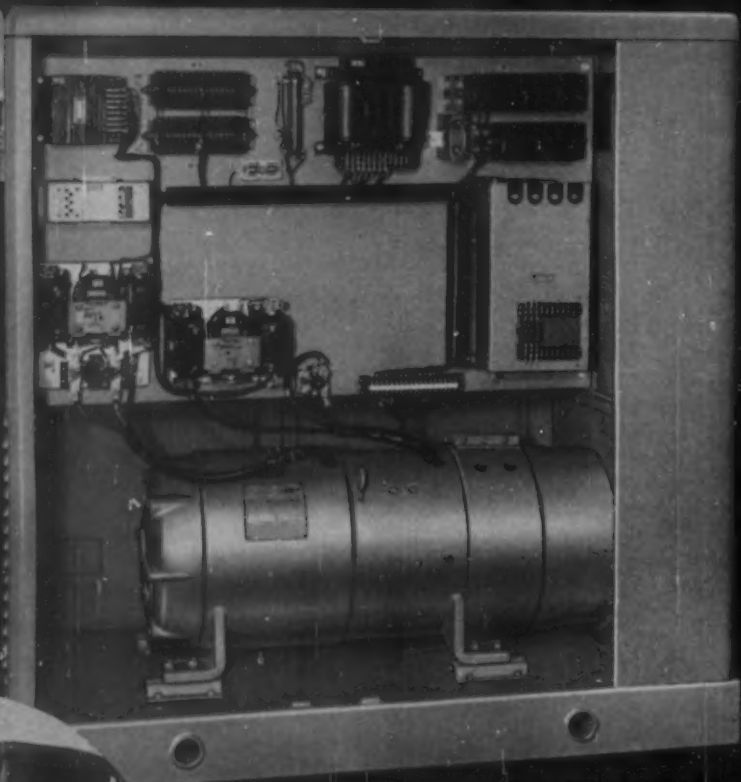
DYNAPAR CORPORATION, 7312 N. RIDGEWAY AVENUE, SKOKIE, ILLINOIS

Circle 333 on Page 19

221

"BUILDING BLOCK" FLEXIBILITY permits adding and removing of circuits in your plant by your own electrician. The 6" x 6" transistor control panels have exceptionally high resistance to heat, moisture, and electrical breakdown.

FINGERTIP OPERATOR CONTROL with start and stop pushbuttons and potentiometer speed-setting dial. Small potentiometers greatly reduce size of operator's control panels and are dust tight for maximum protection.



RUGGED FLEXITORQ motors offer very high commutating ability, 400% short time and 15% continuous overload capacities; fast acceleration and deceleration. Made in various enclosures, these compact motors permit external mounting of gear heads, blowers, tachometer generators, etc., to meet any operating requirement.

DEPENDABLE TRANSISTORS are heavy-duty industrial components rated 35 volts, but stressed to only half their nominal rating in our circuits. They have unusually high gain with twice the speed of response and only half the drift in gain of tubes. Transistors never fade — normally provide 15 or more years of dependable service.



It's ideal for single-motor and
synchronized multi-motor drives for:

Extruders
Wire-drawing machinery
Machine tools
Conveyors
Calenders
Paper machinery
Textile machinery
Printing presses
Test stands
Adjustable frequency
power supplies
and many other applications

Another NEW product from Louis Allis

The New LOUIS ALLIS Select-A-Speed® Drive —First with field-proved All-Transistor Control

**a high-gain, high-performance d-c drive with unmatched
flexibility and low upkeep**

Here's a superior adjustable speed drive with simplified transistor-magnetic amplifier control. It's the easiest drive to set up and operate. A twist of the dial gives you stepless speed adjustment from zero to full speed in either direction. Each adjustment is independent, thus sparing you the need for compensating adjustments of inter-related settings. You get more consistent day to day operation because transistors — *unlike tubes* — are highly dependable.

The new Select-A-Speed defies obsolescence. To add functions, such as current limit, to your basic drive, you simply have your electrician install the "current limit" transistor circuit panel. These "building-block" panels allow you to add any of the 13 control circuits that changing conditions call for — and they are immediately available from Louis Allis stock. Thus a rebuilding or adaptation job that, on former equipment, cost thousands of dollars — excluding down-time — can now be done at a fraction of the cost and time *right in your own plant!*

Transistor control practically eliminates upkeep and down-time. High quality transistors, field proven in missiles and other advanced electronic equipment, assure you of a high degree of dependability with a life expectancy of 15 or more years. Printed low-voltage transistor circuits are virtually trouble-free and can be quickly and easily replaced from low-cost stock.

Further savings are provided by the new Louis Allis Flexitorq® drive motors through vastly improved commutation, low brush wear, and their ability to safely withstand momentary overloads of 400% of normal horsepower rating.

If you want superior speed regulation on your drive, check the new Louis Allis Select-A-Speed with *all-transistor* control. Sizes from 5 to 400 hp — in a wide range of enclosures and speed ranges up to 20:1. Contact any one of the 60 Louis Allis District Offices for information and application assistance. Or write for bulletin 2001 to The Louis Allis Co., 459 E. Stewart St., Milwaukee 1, Wisconsin.



MANUFACTURER OF ELECTRIC MOTORS AND ADJUSTABLE SPEED DRIVES

LOUIS ALLIS



shortest
distance
between you
and
RELIABILITY!



division of
INDUSTRIAL TIMER CORPORATION

RELAYS

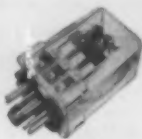
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Factory Tested for Reliability!

GENERAL PURPOSE
Open Type Relay. Up to
3PDT, 5 or 10 amp con-
tact rating. Voltages up
to 230 volts, AC or DC.
Details in Bulletin 10.



GENERAL PURPOSE
Plug-In Type Relay. Con-
tact arrangements up to
3PDT, 5 or 10 amp con-
tact rating. Voltages up
to 230 volts, AC or DC.
Details in Bulletin 10.



PRINTED CIRCUIT Open
Type Relay. Up to 3PDT.
5 or 10 amp contact
rating. Voltages up to
230 volts, AC or DC.
Details in Bulletin 11.

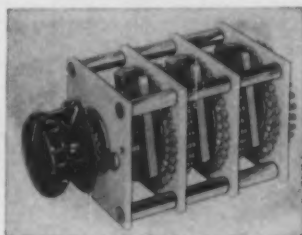


211 River Street, Orange, N. J.
Industrial Relays, Foot Switches, Buzzers, Coils
Phone: ORange 2-8200

Circle 335 on Page 19

NEW PARTS AND MATERIALS

(Continued from Page 221)



dictate. Flexibility permits use of the switches in circuit experimentation, laboratory work, and breadboards, as well as standard applications. Switches are built in square configuration, in 1 3/4 and 2 1/4-in. sizes. They are corrosion-resistant metal and inorganic, fiber-filled plastic, capable of withstanding high temperatures. They meet and exceed all applicable paragraphs of MIL-S-3786 and MIL-E-5272. Dav-
en Co., Livingston, N. J.

Circle 567 on Page 19

Lubrication System

of anodized aluminum

Trio control contains an automatic moisture-ejection filter, a piston-type, self-relieving regulator, and a mist-type lubricator. Made of anodized aluminum, it provides conditioned



air for all pneumatic devices. Air-
matic Valve Inc., 7313 Associate
Ave., Cleveland 9, Ohio.

Circle 568 on Page 19

Synchronous Motor

has output speeds
of 300, 600, or 1200 rpm

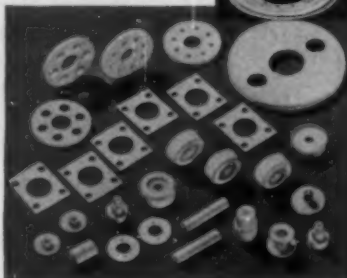
Type 5001 ac hysteresis synchronous motor, with output speeds of 300, 600, or 1200 rpm, operates from 115 v ac to 60 cycles. It drives tapes in combinations of 3 3/4, 7 1/2, and 15 ips, or 7 1/2, 15, and 30 ips. Mo-

Fabrication...

**THE MOST
IMPORTANT
STEP IN
TEFLON***



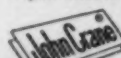
*Du Pont Trademark



For instance, Crane Packing Company's new Teflon products plant was especially designed to obtain the highest quality fabrication of this material and includes the very latest in extruding, molding, curing and machining equipment. Result: parts and components that retain all of Teflon's outstanding electrical, mechanical, anti-corrosive, heat-resistant and other properties.

Whether you get this quality depends on your selection of a fabricator. Why not choose the best?

Contact us about
your requirements.
Request Bulletin T-110.



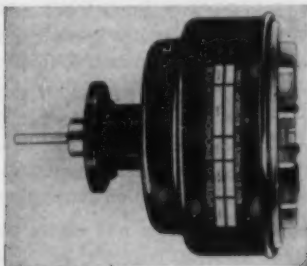
CRANE PACKING COMPANY

6425 Oakton Street, Morton Grove, Illinois
(Chicago Suburb)

In Canada: Crane Packing Co., Ltd., Hamilton, Ont.

Circle 336 on Page 19

tor is insensitive to voltage changes of 40 v in either direction. Inherent gyroscopic action of the motor enables smooth, pulse-free operation. Unit incorporates sealed, prelubricated bearings. Rotor revolves around the outside of the stator, and motor ring acts as a permanent magnet. Unit operates in an ambient temperature range of -65 to $+165$ F. Minimum synchronous rotor torque is 7 oz-in. Stainless-steel, hard-chrome-plated capstan runout



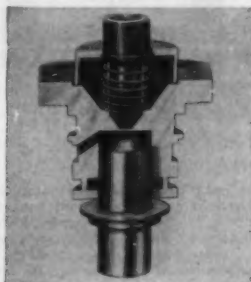
is less than 0.00015 in. maximum. Beau Electronics Inc., Waterbury, Conn.

Circle 569 on Page 19

Pressure Indicators

for system working pressures to 10,000 psi

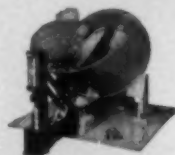
Deltadyne pressure and differential-pressure indicators are available for a wide range of industrial and airborne applications. They operate on a magnetic principle which eliminates the need for mechanical linkages. Red button on top of the indicator gives positive visual indication of excessive pressure drop. Actuating pressure can be adjustable or factory-set, and unit can be connected by piping, tubing, bolts, or mounted in a cavity. Indicators are available for system working pressures to 10,000 psi, operating temperatures from -65 to $+275$ F, and



November 23, 1961



VIBRATORY FEEDER for light, fragile or highly finished parts.



ROTARY FEEDER for high production feeding.



ROTARY HIGH SHELL FEEDER for maximum holding capacity.



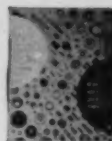
Shuffle and deal parts for automatic assembly with

DPS selective feeders

It takes fast, automatic feeding to satisfy the appetites of today's automatic assembly machines. And nowhere can you duplicate the range of equipment, the specialized experience in selective feeders offered by Detroit Power Screwdriver Company.

The most complete line in industry, DPS parts feeders include rotary, vibratory and elevator types. They handle any product from the tiniest of screws to assembly components the size of your fist . . . range in holding area from eighty cubic inches to 20 cubic feet.

DPS will welcome an invitation to analyze your assembly operations. If lagging production can be traced to inefficient feeding, the problem is as good as answered. Write for catalog on selective feeders.



DETROIT POWER SCREWDRIVER COMPANY

19,000

2801 W. Fort St. • Detroit 16, Michigan
A Subsidiary of Link-Belt Company

Circle 337 on Page 19

225

SPEED IT UP...SLOW IT DOWN...

**ONLY THIS DRIVE
IS SIMPLEST,
MOST ECONOMICAL
...TROUBLE-FREE**

The drum at the top—it could represent one of your machines—changes speed smoothly with each turn of the handwheel. Of at least four ways to do this with simple V-belt drives, only the Worthington Variable Speed Motor Pulley system is so simple, so trouble-free.*

What is so different? In any V-belt system you must, of course, keep the belt perfectly aligned or increased wear will result. The Worthington drive does this perfectly... automatically. The illustration shows how.

See how the motor and motor pulley are mounted on Worthington's exclusive Angle-Matic base. The motor travel is at a slight (but precise) angle to the line of the belt. So, as the handwheel is turned, the inner motor pulley flange moves laterally in exact synchronization to its widening gap. And the spring-loaded outer flange stays in perfect alignment, too.

Now compare the Worthington Angle-Matic base and the simple, single-moving-flange Motor Pulley with other systems. One requires a highly complex dual-moving flange pulley. Another requires two adjustable sheaves. A third uses a substitute for the true V-groove companion sheave. None are so simple or trouble-free.

This is just one example of how Worthington gives you more value in variable speed drives. This Motor Pulley produces speed ratios up to 3:1 and is available for $\frac{1}{4}$ th to 15 hp. For more information, please contact your nearest Worthington distributor listed in the Yellow Pages. Or write Worthington Corporation, Section 79-36, Oil City, Pa.

PRODUCTS THAT WORK
FOR YOUR PROFIT



*How does it work? As the handwheel turns one way, it pulls the motor back from the drum; the belt forces itself deeper in the motor pulley; the flanges move apart, effectively reducing the pulley diameter. Because the motor turns at constant speed, the smaller pulley diameter causes the drum to slow down. Turn the handle the other way, the drum speeds up. Up to 3:1 speed change is made by this Worthington drive.

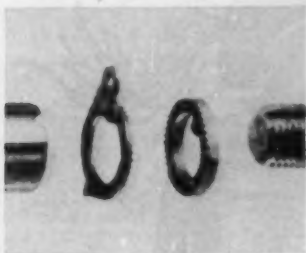
actuation from 1.5 to 100 psid. Designed for corrosive service, units have housings of aluminum or stainless steel. **Pall Corp.**, 30 Sea Cliff Ave., Glen Cove, N. Y.

Circle 570 on Page 19

Index Locking Device

adjusts control linkage
and cylinder rod ends

Positive index locking device used by the aircraft industry for precise linear and angular adjustment of control linkage and cylinder rod ends is now available for industrial use with similar adjustment problems. Conforming to NAS specification 1193, device consists of two invest-



ment-cast serrated washers, with each notch representing 0.001-in. linear adjustment. Turning the correct number of notches provides the exact adjustment required. Available sizes range from 0.260 in. ID and 0.44 in. OD to 2.265 in. ID and 2.88 in. OD. **Arwood Corp.**, 321 W. 44th St., New York, N. Y.

Circle 571 on Page 19

Hydraulic Line Filter

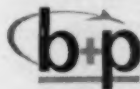
has built-in
condition indicator

Periodic inspection of hydraulic line filters is eliminated in new unit which incorporates a filter condition indicator. Built-in pressure gage indicates at a glance when the filter element is in need of cleaning or replacement. Full-flow filter is 1/2-gal size with 1 1/4-in. NPTF ports at inlet and outlet. It can be installed in either the suction line or the return line. Built-in bypass valve protects the filter element. Operating temperature range is -65 to +300 F; maximum operating pressure is 100 psi. With wire-cloth element, filter passes up

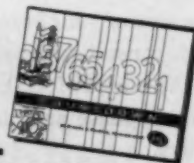


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**HURDLE THORNY
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... a line of industry-wide favorites, built to make tough applications seem easy

When it comes to building electric motor-powered equipment, *make sure of your horsepower source.* Before you specify any motor brand, consult with your A. O. Smith Motor Man. He'll show you how the horses of A. O. Smith (a full line of integrals and fractionals both polyphase and single-phase) help users surmount application barriers.

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Through research  ... a better way

A.O. Smith
CORPORATION
ELECTRIC MOTORS

Tipp City, Ohio

A. O. SMITH INTERNATIONAL S. A.
Milwaukee 1, Wisconsin, U. S. A.

A CASE IN POINT



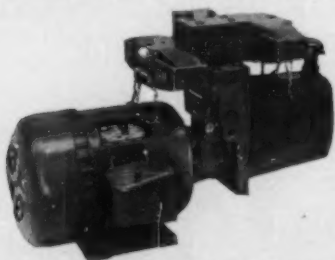
A TEAM THAT PULLS TOGETHER

Latest development in the industrial line of Vickers Inc. (Division of Sperry Rand Corporation) is its new PK line of motorized hydraulic power packages. These versatile units have a wide range of use on small machine tools, presses, paper machinery, textile machines plus countless other industrial applications.

Being "Jacks of all trades" PK power packs required a motor that would team up efficiently for all kinds of service—a motor that could operate on unusual applications yet still be custom-engineered for the particular job it had to do. Vickers had to be particular — that's why they chose A. O. Smith totally enclosed fan cooled motors.

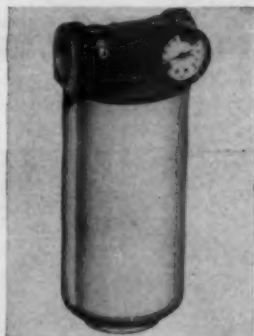
A. O. Smith motors are current choices wherever a simple, compact, powerful unit is needed—in the case of Vickers PK, a motor built for years of reliable hydraulic power and control. Simple and compact because the entire package is close-coupled... with splined motor shaft for ease of assembly and disassembly. Reliable because of exclusive A. O. Smith TEFC features — die cast rotor, efficient cooling system, permanently lubricated bearings, reserve insulation protection.

You'll find it pays to team up with A. O. Smith motors — mechanically and electrically, you get more for your motor dollar when you put your money on the horses of A. O. Smith.



A RELIABLE TEAM — New Vickers PK motorized power pack powered by an A. O. Smith TEFC motor — a combination that runs without a hitch.

NEW PARTS AND MATERIALS



to 60 gpm with a pressure drop of only 5 psi. Gresen Mfg. Co., 405-35th Ave., N. E., Minneapolis 18, Minn.

Circle 572 on Page 19

Two-Part Adhesive

for high-temperature applications

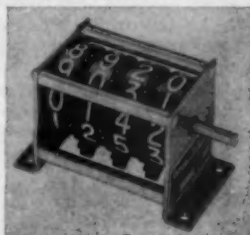
Available for ultra-high-temperature applications, Eccobond 104 is a two-part epoxide adhesive with excellent dimensional stability. Material is used as a bonding agent for metals, ceramics, and plastics. It is particularly useful as a strain-gage adhesive, showing good adhesion at temperatures over 500 F. Liquid and finely divided powder are mixed in a ratio of 100:64, providing a smooth-flowing material with a pot life of at least 24 hr at room temperature. Curing schedules are flexible, depending on the desired application. Emerson & Cuming Inc., Canton, Mass.

Circle 573 on Page 19

Reversible Counter

has nylon drums and pinions

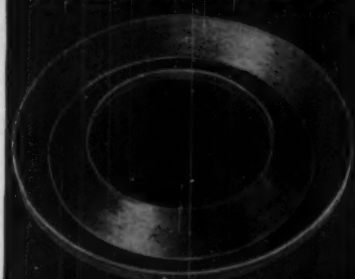
Model 3522 reversible counter has digits 27/64 in. high on 1 7/16-in. diam drums. Drums and pinions are molded nylon with the numbers hot stamped or silk screened. Shafts



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- **LEATHER**—Wide variety of leathers and impregnants to accommodate a wide range of temperatures, pressures, and mediums.
- **HOMOGENEOUS RUBBER**—Natural and synthetic rubbers—especially compounded and processed for specific applications.
- **COMPOSITION**—Includes cotton and asbestos duck impregnated with synthetic rubbers, especially processed for type of fluid or medium and temperature and pressure conditions.

All Chicago-Allis packings are available with anti-friction impregnations or coatings.

Whether it is a problem of higher pressures, higher temperatures, extreme operating conditions, or unusual compounds or liquids... or just a matter of plain efficiency, economy, and dependability... there is a Chicago-Allis packing especially suited for the application. C-A products are used across industry... automotive, aircraft, home appliances, agricultural equipment, machine tools, and ordnance equipment. Just ask for the assistance of C-A engineers who are always available for counsel on your packing requirements.



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Packing
Handbook
**WRITE FOR
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CHICAGO-ALLIS

MFG. CORP.

127 N. GREEN ST. CHICAGO 7, ILL.

Circle 341 on Page 19

ADVANTAGES OF FLEXIBLE SHAFTING

For Power Drive and Remote Control

by

C. Hotchkiss, Jr.

Application Engineer

Stow Manufacturing Co.

Flexible shafting has the following advantages over other type drives:

- 1—it is often the simplest method of transmitting power between two points which are not collinear or which have relative-motion
- 2—eliminates exposed revolving parts
- 3—does not require accurate alignment
- 4—easy to install and maintain

Not Collinear—Where it is necessary to connect two shafts which are not collinear, a simple arrangement of a single belt or two universal joints will often do the job adequately. But, in many cases where the path of transmission is more complicated and would require a more expensive arrangement of mechanical components, flexible shafting provides a simple, low cost, efficient drive which is easy to install because it does not require accurate alignment. See example, figure 1, in which a 1½-inch Stow flexible shaft is used to drive the auger on a G.L.F. bulk feed truck.

Flexible shafting also allows the designer greater freedom in locating either the drive or the driven component on a piece of equipment.



Fig. 1



Relative Motion — Where two shafts which have relative motion must be connected, flexible shafting is often the ideal means of transmission. In many cases it eliminates a much more complicated drive which would, necessarily, include telescopic joints; further, it eliminates the danger of exposed moving parts. See figure 2, which shows a ¾-inch Stow flexible shaft driving an Avery Rake built by the Minneapolis Moline Co.



Fig. 2

Other typical applications of this type are used on portable power tools when motors are too heavy to be mounted on the tool—such as portable grinders, sanders, paint scrapers, saws and tree tappers. And, since flexible shafting is not affected by vibration, it is an ideal drive for applications where a high degree of vibration is involved—such as in vibration testing tables and concrete vibrators. Stow flexible shafts are available: for power drive applications in diameter sizes from ½-inch to 1¼-inches; for remote control applications in diameter sizes from ¼-inch to 1½-inches. The 1¼-inch power drive shaft will transmit up to 10 HP while the 1½-inch remote control shaft will transmit up to 4000 lb. in.

For complete engineering data on flexible shafting, including selection charts, write for engineering bulletin 570.

STOW MANUFACTURING CO.

11 SHEAR STREET

BINGHAMTON, NEW YORK

NEW PARTS AND MATERIALS

are stainless steel in a nickel-silver frame assembly. Unit is available either with Oilite or ball bearings. Over-all package size is 1 11/16 in. wide by 2 in. high by 3 3/16 in. long. Haydon Instrument Co., 17 Brown St., Waterbury 20, Conn.

Circle 574 on Page 19

External Vibrators

are available in three sizes



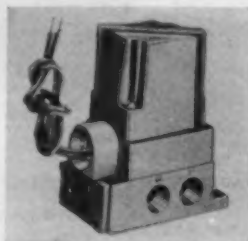
Heavy-duty, electric external vibrators have a shortened shaft between bearings to reduce bearing strain and minimize bend in the shaft at high speeds. They are available in three compact sizes with impacts from 500 to 1400 lb. Vibrators are noiseless, and are totally enclosed with adjustable eccentrics to fit any need. Tremix Co. Inc., 94 Henry St., Binghamton, N. Y.

Circle 575 on Page 19

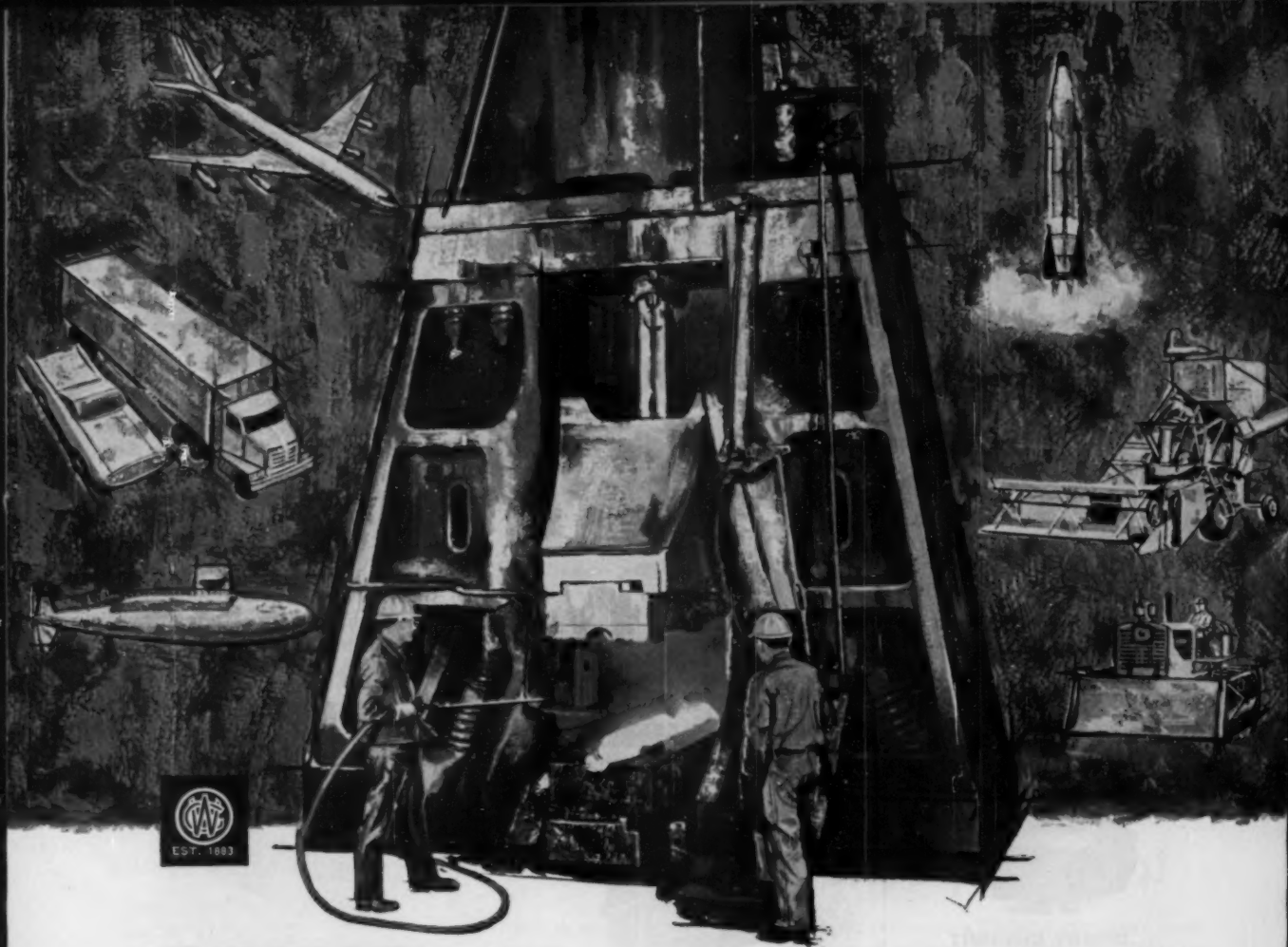
Air-Control Valve

has large flow capacity

Compact four-way, two position, pilot-operated, air-control valve is designated Series GG200. It is 3-11/32 in. long, 1 7/8 in. wide, and 3 7/8 in. high. Valve combines large flow capacity with quick shift to provide fast response time. High-strength aluminum, treated for corrosion resistance, is used throughout the unit for long life and light weight. Low-wattage solenoids require 7.7 w to operate, making pos-



MACHINE DESIGN



GIVING METAL NEW MUSCLE BY FORGING

*...a specialty Wyman-Gordon knows best
and is best equipped to perform for you*

Specify "punishing service" in any environment—land, sea, air or space—and there is no substitute for a forging's endurance. Likewise, specify reliability in your supplier and there is no substitute for experience.

Here Wyman-Gordon has the outstanding record. Our background in hot working all forgeable materials covers more than three-quarters of a century. From it have come most of today's major advances—in forging techniques, metallurgical controls and development of facilities for extending size and complexity of forged parts. This accumulated know-how has done much to make Wyman-Gordon "forging headquarters" for an impressive list of industrial leaders.

Most likely our experience in saving weight, adding strength and reducing machining cost on countless other parts—can do as much for yours. To get expert appraisal, ask to have a forging engineer call while designs are still on the board.

WYMAN - GORDON FORGINGS

of Aluminum Magnesium Steel Titanium ... and Beryllium Molybdenum Columbium and other uncommon materials

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WORCESTER MASSACHUSETTS

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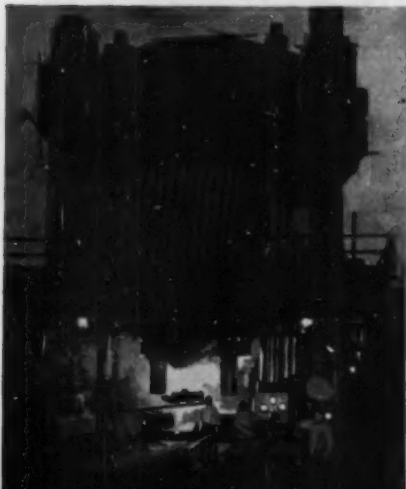
GRAPTON MASSACHUSETTS

LOS ANGELES CALIFORNIA

PALO ALTO CALIFORNIA

FORT WORTH TEXAS

Circle 343 on Page 19



Special Motors are Standard AT PEERLESS ELECTRIC!

Need a special motor? Our knowledge may aid in reducing the engineering time. We are the exclusive supplier to many manufacturers for motors with unusual operating conditions and duty requirements. Write us your needs!



DRIP-PROOF (open type)

Completely protected against dripping liquids and falling particles.



DIRECT CURRENT

High starting torque, good overload capacity and high electrical efficiency. For rough usage.



EXPLOSION-PROOF TORQUE MOTOR WITH BRAKE



TEPC and EXPLOSION-PROOF

External fan draws cool air across motor toward driven machine.



WEATHER-TIGHT SPECIAL FLANGE



SPECIAL FLANGE REVERSING HOIST MOTOR, SINGLE PHASE

ENGINEERING DATA: Special mountings. Various modifications—special shaft features; paint and varnish treatments, Class A, B, F, H insulation. Peerless builds to standards and specifications of JIC, AIEE (including AIEE No. 45 Marine Duty), ABS, Federal and Military.

WRITE FOR BULLETINS: Space-Saver, SP-1; Torque, T-1; Complete Line, SDA-155. Peerless Electric Division, H. K. Porter Company, Inc., W. Market Street, Warren, Ohio.

PEERLESS ELECTRIC DIVISION

PORTER

H. K. PORTER COMPANY, INC.

PORTER SERVES INDUSTRY with steel, rubber and friction products, asbestos textiles, high voltage electrical equipment, electrical wire and cable, wiring systems, motors, fans, blowers, specialty alloys, paints, refractories, tools, forgings and pipe fittings, roll formings and stampings, wire rope and strand.

NEW PARTS AND MATERIALS

sible the use of simple electrical circuit components. Hannliff Co., Dept. 116, 501 S. Wolf Rd., Des Plaines, Ill.

Circle 376 on Page 19

Mechanical Limit Stops

for 0-10 and 0-40 turns

Improved precision subminiature mechanical limit stops incorporate a post-construction design, providing a sturdy, rigid structure. Result is a minimum of inertia and starting torque with a high static torque. BuOrd sizes 5 and 8 include stainless-steel BuOrd servo-mounting plates, hardened and ground shafts, and phosphor-bronze traveling nuts for smooth operation and long wear. Basic models are designed for 0-10



and 0-40 turns. Units conform to MIL-E-5272C, and have a nonjamming stop-pin arrangement. Repeatability is within 3 min of arc. Torque rating for Size 5 is 50 oz-in.; torque rating for Size 8 is 160 oz-in. Northfield Precision Instrument Corp., 4400 Austin Blvd., Island Park, L. I., N. Y.

Circle 377 on Page 19

Gasket Sheetting

of rubber and asbestos

Two series of rubber-asbestos gasket sheetting in the form of continuous rolls are available. Duroid 3100 is neoprene rubber and asbestos; Duroid 3200 is nitrile rubber and asbestos. Use of the beater-addition process provides a homogeneous blend of asbestos fiber and latex. Formulations contain no volatile or extractible plasticizers. Gaskets cut from either series have clean-cut edges and uniform thickness. Three grades, ranging from firm to highly compressible, are available in both series. Standard rolls are available in 0.015 and 0.031-in. thickness in

50-in. widths. Lengths vary with the grade. Duroid 3100 is recommended for use in oil, gasoline, and Freon systems, and in water systems with antifreeze. Duroid 3200 has resistance to hydrocarbons and is recommended for use in oil and gasoline systems. Rogers Corp., Rogers, Conn.

Circle 578 on Page 19

Explosive-Actuated Nuts

accommodate bolt thread sizes from $\frac{1}{4}$ to $1\frac{1}{2}$ in.

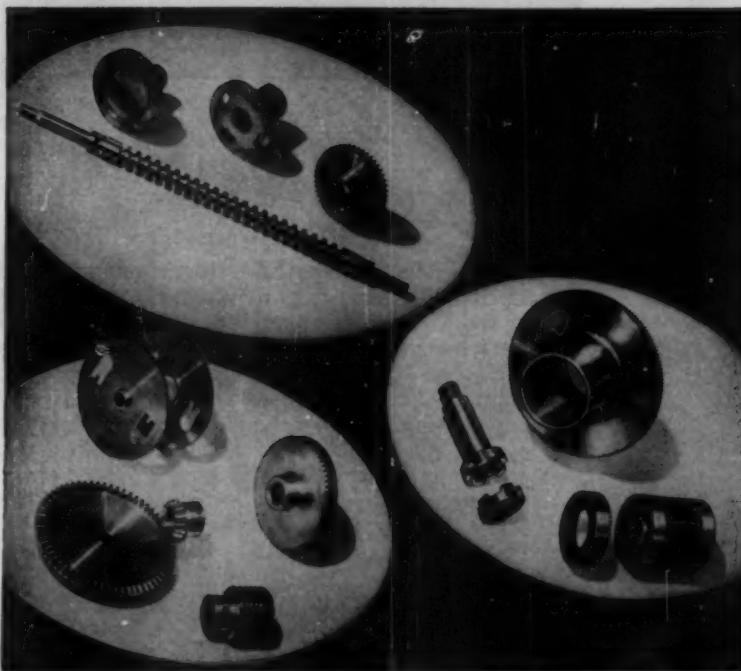
Explosive-actuated nuts provide 0.002-sec release from a standard AN bolt. Models accommodate standard bolt thread sizes from $\frac{1}{4}$ to $1\frac{1}{2}$ in. They meet the strength requirements of the bolts with which they are used. Nuts are for use in temperatures from -65 to $+160$ F. Conax Corp., 2300 Walden Ave., Buffalo 25, N. Y.

Circle 579 on Page 19

Solenoid-Operated Valve

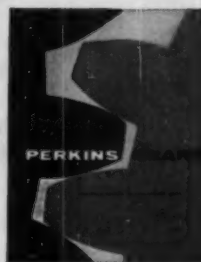
for temperatures from 40 to 175 F

Straightway, Pacer solenoid-operated Headline has been added to a series of lightweight, inline, air-control valves. Body and poppets of anodized-aluminum alloy reduce wear, corrosion, and weight. Small, light, moving parts and short poppet travel assure rapid response with minimum impact energy and pressure drop. Synthetic rubber seals automatically compensate for wear. Solenoid is rated for continuous-duty operation at $+5$ or -15 per cent of rated voltage for the standard air-pressure service specification. Standard voltages are 115, 230. Standard frequency is 60 cycles, available in most ac and dc volt-



small and fine pitch gears for precision equipment

No matter how fine your gear requirements — Perkins can solve your problems. Perkins unique custom-gear engineering service, available to your engineering staff prior to the blueprint stage, will... eliminate production headaches... cut excessive costs. This service — recognized by leaders in the radar, electronic and missile fields, and backed by 52 years of custom gear experience — assures the precision quality needed to guarantee trouble-free operation. Don't gamble with gear performance... Perkins skilled personnel, together with modern up-to-date equipment guarantees fast delivery on prototypes or production runs. Call or write Perkins for complete information on custom-gear engineering and a quotation on your requirements. Then judge for yourself.



YOURS ON REQUEST
Folder showing custom gears Perkins has made (from various materials) for aircraft, automotive, precision instruments, home appliances, portable and machine tools, and other products. Includes Perkins facilities for producing various gear types and sizes. Write today.



PERKINS

MACHINE AND GEAR CO.

Dept. 73 West Springfield, Mass.
Telephone: REpublic 7-4751

IMPERIAL D-C MOTORS

*for Dependable
Heavy-Duty Service*

Imperial D-c Motors meet the ever-increasing demand for dependable, heavy-duty drives in nearly every industry today. Over seventy years of d-c design and application experience is behind the manufacture of these motors. Ratings from 1 through 125 hp., for constant or adjustable speeds with shunt, series or compound windings are available in all standard enclosures. When you choose *The Imperial Line* you are assured of motors that stay on the job longer... keeping production high at lower costs. Write for bulletin or contact the sales office nearest you.

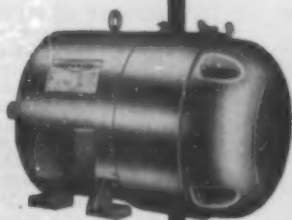
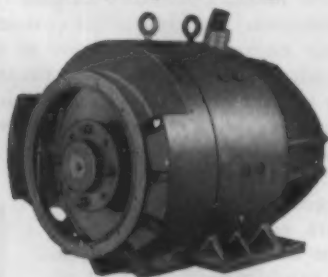


ELECTRIC COMPANY
84 Ira Ave. • Akron 9, Ohio



Semi-Guarded D-C Motor

**Drip-Proof D-C Generator,
SAE Flange Mounting**



**Totally-Enclosed
Fan-Cooled D-C Motor**

**Two-Bearing
Motor-Generator Set**



NEW PARTS AND MATERIALS

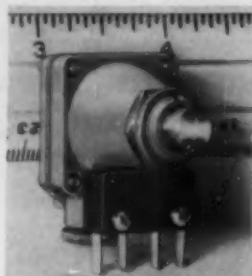
ages, 25 through 60 cycles. Unit accommodates pressures in head from 30-150 psig, and in body from 5-150 psig. Temperature range is 40 to 175 F. Ross Operating Valve Co., 120 E. Golden Gate Ave., Detroit 3, Mich.

Circle 580 on Page 19

Pneumatic Timer

has time range of
0.2 to 15 sec

Model 90 miniature pneumatic timer is 1½ in. square and weighs less than 1 oz. It is basically a flush-mounted component, but is furnished with a universal mounting bracket for mounting in any place and in any position. Time range



is adjustable from 0.2 to 15 sec. Easily replaced switch is rated at 10 amp. Timer operates within a repeat accuracy of ± 10 per cent in temperatures of 32 to 120 F. Hagen Mfg. Co., 104 Walnut St., Baraboo, Wis.

Circle 581 on Page 19

Tube Joint

for 150-lb service

Flexmaster tube joint is available in tube sizes from 1 through 4½ in. Joint meets ASA requirements for 150-lb service, and withstands temperatures from -30 to +250 F. Tubes can be joined quickly without flanging, threading, welding, grooving, or other tube-end preparation. Up to 4 deg angular misalignment and axial tube adjustment is permitted without leakage. Vibration and shock are absorbed by soft, thick rubber of the gasket. All other components are corrosion-resistant, cadmium-plated steel with post chromate bronze finish. With one nut and bolt on each coupling

If you design, specify or purchase
**POROUS BRONZE and POROUS IRON
 BEARINGS**

this 40-page FREE book

**BELONGS
 TO YOU
 !**



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Cored Bars, Solid Bars and Plates.....	39-40

A glance at the Contents above will tell you this book should be at arm's reach for quick reference whenever porous bearings are on your mind. In the many pages on Standard Bearing Sizes, for instance, literally hundreds of thousands of possible combinations of diameters and

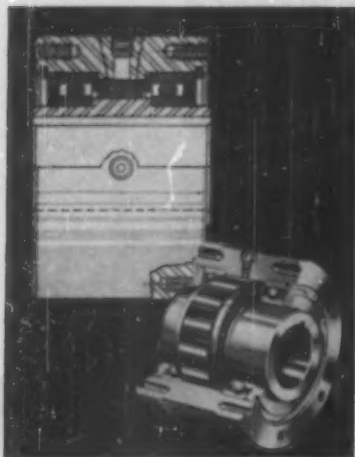
lengths are offered—enabling you to select exactly the right size Keystone bearing for your needs, with code number for easy ordering and fast delivery. • Ask for this useful brochure on your letterhead, please. We'll send a copy promptly, without obligation of any kind.

Keystone CARBON COMPANY
 ST. MARYS, PA.

POWDERED METAL PARTS DIVISION

LEADERSHIP IN POWDERED METAL RESEARCH, DESIGN, AND MANUFACTURE SINCE 1927

Circle 347 on Page 19



For indexing rates
to 1200 strokes/min.

HPI Clutches

Whenever indexing requirements exceed 150 strokes per minute or 90° per stroke, then Formsprag HPI clutches present the ideal solution. Proved the finest indexing clutch on the market today!

- Torque capacities from 140 to 13,500 lbs. ft.
- Bore diameters from .500" to 6.000".
- More torque for a given size and weight.

Write for
Formsprag Catalog 105B



**FORMSPRAG
COMPANY**

23603 HOOVER ROAD, DEPT. 124
WARREN (DETROIT), MICHIGAN

Precision Power Transmission Products

Circle 348 on Page 19

NEW PARTS AND MATERIALS



end, joint is suitable for quick break-away connection. Marman Div., Aeroquip Corp., 11214 Exposition Blvd., Los Angeles 64, Calif.

Circle 582 on Page 19

Stressed Panel Fastener

is smaller than
NAS 547 Size O

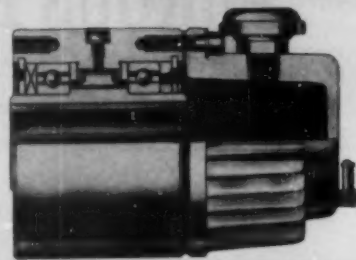
Miniature Zip-Loc stressed panel fastener, smaller dimensionally than NAS 547 Size O, has the shear strength of a Size O fastener. Ser-rated mating surfaces lock the nut to stud in any position. Complete receptacle assembly consists of six simple parts. Internal stud is self-aligning, insuring positive alignment of top sheet. Double shear strength is 5440 lb, and ultimate tensile rating is 1000 lb. Deutsch Fastener Corp., P. O. Box 61072, Los Angeles 61, Calif.

Circle 583 on Page 19

Footless Gear Motor

from 1 to 5 hp,
230 to 780 rpm

Designed for direct connection to the driven machine, Type GH Unimount Syncrogear is available with NEMA Style C or D brackets in 9 and 10 $\frac{7}{8}$ -in. face-plate diam. The single-reduction unit incorporates asbestos-protected windings, normalized castings, precision-honed gears, and solid-shank, high-speed pinions. It is available from 1 to 5 hp, 230 to 780 rpm in dripproof, totally enclosed, and explosionproof



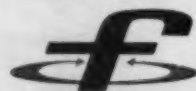
Prevent Runback
of Conveyors and
Similar Equipment

HSB Clutches

Eliminate reverse rotation on conveyors, transfer machines and similar equipment with precision built Formsprag HSB, high-speed backstopping clutches.

- Effective seals, oil reservoir with sight glass and filter breather add up to reduced maintenance.
- Select torque capacities from 140 to 1900 lbs. ft.
- Choose bore diameters from .500" to 2.750".
- Exclusive Formchrome sprags permit more capacity for given clutch size and weight.

Write for Catalog 105B.

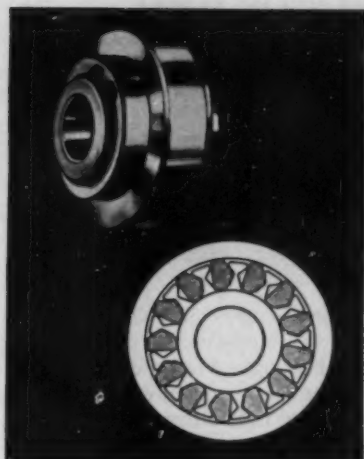


**FORMSPRAG
COMPANY**

23603 HOOVER ROAD, DEPT. 125
WARREN (DETROIT), MICHIGAN

Precision Power Transmission Products

Circle 349 on Page 19



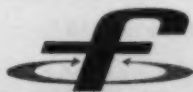
Miniature Clutches

FOR INDEXING, OVER-RUNNING, BACKSTOPPING

Two models offer high continuous over-running speeds (FS-02 to 3450 rpm and FS-04 to 2400 rpm) and indexing rates up to 5,000 cycles per minute—15% higher than previous models.

- Model FS-02 has 4.5 ft. lbs. torque capacity with 250" bore and Model FS-04 has 17 ft. lbs. with .375" or 500" bores—tops for their size and weight.
- Each sprag is individually energized, insuring ultra-high performance.
- Gears, sprockets, etc. can be mounted to either outer race hub or to outside diameter of clutch.

Write for Catalog 105B



**FORMSPRAG
COMPANY**

23603 HOOVER ROAD, DEPT. 126
WARREN (DETROIT), MICHIGAN

Precision Power Transmission Products

Circle 350 on Page 19

NEW PARTS AND MATERIALS

designs. U. S. Electrical Motors Inc., Box 2058 Terminal Annex, Los Angeles 54, Calif.

Circle 584 on Page 19

Vitreous-Enameled Resistors

in values from 1-6000 ohms

Miniature, 1-w, vitreous-enameled resistor is available in 63 values from 1 to 6000 ohms. Units provide high stability under constant, full-rated load, long life, high over-



load capability, and low noise level. Size of less than 9/16 in. long x 1/8-in. diam, and small axial leads make the resistors adaptable to modular and printed-circuit wiring applications. Ohmite Mfg. Co., 3693 Howard St., Skokie, Ill.

Circle 585 on Page 19

Soft Packing

for solvent and mild acid
or mild alkali service

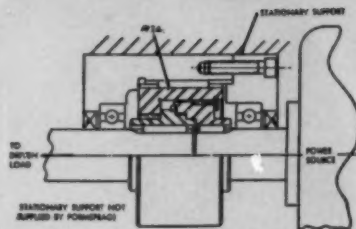
Garlock 5555 is a plastallic packing which has a powdered Teflon-asbestos fiber core and a single, non-metallic, braided-asbestos-yarn jacket, impregnated with Teflon suspensoid. Available as a packing for solvent and mild acid or mild alkali service, packing is suitable for use in situations where noncontamination is an essential requirement. Packing is furnished in sizes of 1/8 through 1 in. in 1/16 in. increments. Garlock Inc., Palmyra, N. Y.

Circle 586 on Page 19

Precision Component Hangers

accommodate various
sizes of ball bearings

Some types of new component hangers are used as shaft supports, and in the assembly of breakboard servo devices. Others are available in a wide range of sizes to fit standard rotating computer components.



Reverse Locking Clutches

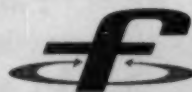
FOR POSITIVE LOAD POSITIONING

Sketch above shows why the load "stays put" once the power source is stopped. Any possible motion of driven load is arrested by R-L clutch acting on the stationary support.

- There is no backlash or feed-back torque in this high precision device.
- Long life is assured by high efficiency sprags.
- Simplicity of design means minimum number of moving parts.
- Compact units for torque capacities from 40 lbs. in. to 30,000 lbs. in.
- Bores and shaft sizes range from 1/4" to 2 1/2".

Write for

RXL (reverse locking) literature

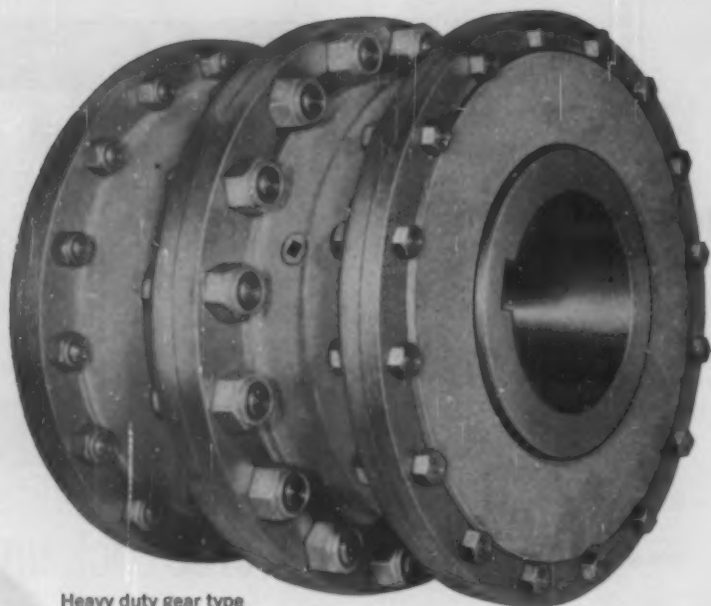


**FORMSPRAG
COMPANY**

23603 HOOVER ROAD, DEPT. 127
WARREN (DETROIT), MICHIGAN

Precision Power Transmission Products

Circle 351 on Page 19



Heavy duty gear type

Up to 6,000 hp per 100 rpm

Here's the coupling with all the muscle you need for heavy duty slow speed mill drives. The machined surfaces of each high grade steel casting are given a fine tool finish within strict tolerances. Waldron mill type couplings are easy to assemble, and seal tight against dust, moisture, and loss of lubricant. The standard sizes listed below are available for quick delivery. Write for Data Sheet S-1050.

Size and nominal bore	HP/100 rpm	Max. rpm
7	1,282	1,950
8	1,912	1,720
9	2,662	1,550
10	3,675	1,400
11	4,950	1,275
12	6,000	1,200

WALDRON-HARTIG, Box 791, New Brunswick, N. J.
a division of Midland-Ross Corporation



WALDRON

Makes it easy to pick the right



Circle 352 on Page 19

NEW PARTS AND MATERIALS



Bearing hangers include two heights, and accommodate various sizes of ball bearings. Available from stock, hangers are machined for squareness from rigid aluminum-alloy castings, and are black anodized. Sterling Instrument Div., Designatronics Inc., 17 Matinecok Ave., Port Washington, N. Y.

Circle 587 on Page 19

Low-Pressure Indicator

for range of
0-40 in. water

Model 8007 sensitive, low-pressure gage has application in ground- support and flight equipment and in many commercial installations. Non-corrosive sensing diaphragm provides high sensitivity. All seals are metallic. Range is 0 to 40 in. of water; accuracy and repeatability, ± 1 in. of water. Operating temper-



ature is -65 to $+185$ F. Diameter is 2 in., length 3.9 in., and weight, 12 oz. Aero Mechanism Inc., 7750 Burnet Ave., Van Nuys, Calif.

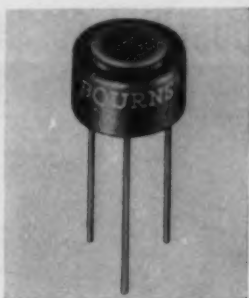
Circle 588 on Page 19

Single-Turn Potentiometer

has diameter of 5/16 in.

Model 3300 microminiature, single-turn potentiometer with 5/16-in. diam meets cycling humidity requirements and can also be used in potted module applications. Resistance values range from 50 to 20,000 ohms, ± 5 per cent. Power rat-

MACHINE DESIGN



ing is 0.5 w at 70 C, and operating temperature range is -65 to +175 C. Weight of the unit is 0.02 oz. Trimpot Div., Bourns Inc., 6135 Magnolia Ave., Riverside, Calif.

Circle 589 on Page 19

Injection-Molding Material

in a variety of colors

Tenite propionate 325 combines excellent flow characteristics with good permanence properties and surface hardness. Articles molded of the formula are serviceable over a wide temperature range, have good impact strength, and are generally unaffected by a year or more of continuous outdoor exposure. Developed primarily for injection molding, formula is also suitable for processing by extrusion, blow molding, or the thermoforming of extruded sheet. It is available in clear transparent as well as in a wide range of other transparents, and in translucent, opaque, pearlescent, and variegated colors. Eastman Chemical Products Inc., Kingsport, Tenn.

Circle 590 on Page 19

Hydraulic Cylinders

with bores from
1 1/8 to 14 in.

Three basic lines of hydraulic cylinders are now available: 2000-psi units, for use in machine tools; 2000 to 3000-psi, general-purpose



Quality BRUSHES



for any FRACTIONAL H.P. MOTOR



Produced BY THE MILLION



for leading Motor Manufacturers for OVER 50 YEARS

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STACKPOLE CARBON CO., ST. MARYS, PA.

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BEVEL GEAR DIFFERENTIALS FOR POWER TRANSMISSION PROBLEMS

If you now design your own, you may save time and money by investigating SPECON differential gearing and differential transmissions. Service-proven SPECON modules can be economically incorporated into your own designs and tailored to your specific requirements.

The SPECON differential assemblies are produced in ten sizes ranging from fractional to 250 hp... spider torques to 31,500 lb inches. Also available are standard transmissions and custom designs incorporating these rugged compact differentials.

For engineering data, or FREE TECHNICAL BULLETINS on SPECON DIFFERENTIALS, write —



Circle 354 on Page 19

NEW PARTS AND MATERIALS

units, meeting JIC specifications; and heavy-duty, 5000-psi units, designed to work with company's 5000-psi pumps and fluid motors. Bore sizes range from 1 1/8 to 14 in. with 17 different mountings available. Denison Engineering Div., American Brake Shoe Co., 1160 Dublin Rd., Columbus, Ohio.

Circle 591 on Page 19

Speed Control

for U. S. Varidrive motors

New self-locking speed control is available as standard equipment on integral-hp U. S. Varidrive motors. Control assures that any rpm setting will be maintained without drifting or creeping until speed is



changed. Cam and roller lock the speed-changing mechanism until force is applied to the handle. Even a slight force on the handle is sufficient to release the cam and rollers to permit speed adjustments; as soon as the force is removed, the mechanism immediately locks in place automatically without slippage. Motors permit stepless speed changes while running, in a range of precisely adjustable speeds from 2 to 25,000 rpm. Varidrive range from 1/4 to 100 hp. U. S. Electrical Motors Inc., P. O. Box 2058 Terminal Annex, Los Angeles 54, Calif.

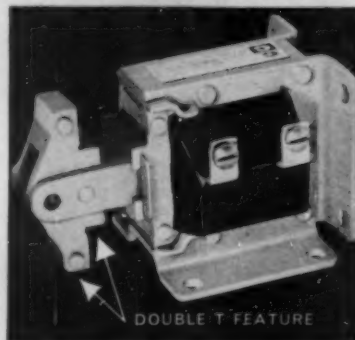
Circle 592 on Page 19

Pressure Switch

for temperatures from -65 to +250 F

Type 1100 miniature pressure switches are available with or without pressure port and with options of solder terminals, potted leads, or electrical connector for electrical

NEW DOUBLE T INDUSTRIAL SOLENOID



Delivers Greater Pull, Faster Cycling, Longer Life

The new 831 series of industrial solenoids designed by Controls Company, the world's largest manufacturer of laminated solenoids, will even out-perform many solenoids of larger size. Check these features:

- Double T plunger provides level pull characteristics with no power drop-off at 2/3 stroke.
- Epoxy encapsulated coil is impervious to water, oil, acid or alkalis.
- Hard chrome plated, beryllium copper core guides assure increased life.
- Heavy coat of epoxy paint on frame and core provides added protection against environmental conditions.
- Universal mounting bracket permits mounting in any position.
- Plunger has reinforced linkage design providing maximum bearing surface.

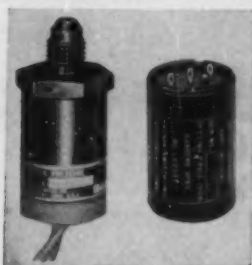
To learn how you can have improved solenoid performance at lower cost, write for Industrial Solenoid Bulletin SL-33 containing pull curves, specifications and performance facts. A complete line of commercial grade solenoids is also available. For information, ask for Commercial Solenoid Bulletin SL-23.



CONTROLS COMPANY OF AMERICA

APPLIANCE AND AUTOMOTIVE DIVISION
9555 SORENG AVENUE
SCHILLER PARK, ILLINOIS

Circle 355 on Page 19



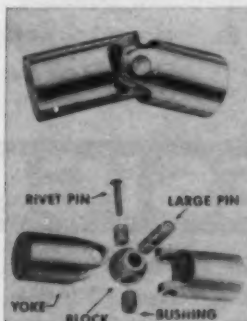
termination. It is recommended that switches without external port be installed inside a low-pressure cabinet or vessel, or within a pressurized system. Weight range is from 0.75 to 2 oz maximum. Switches can be factory adjusted to pressure settings from 10 to 500 psig; proof pressure is 750 psig. Size without external port is $1\frac{5}{8} \times 15/16$ in. diam. Ambient temperature range is -65 to $+250$ F. Haydon Switch Inc., Waterbury 20, Conn.

Circle 593 on Page 19

Universal Joints

in $\frac{3}{8}$ to 3-in. size
for speeds to 1750 rpm

Heavy-duty industrial universal joints provide high horsepower capacity at speeds to 1750 rpm. Single joints provide smooth, sensitive operation through a full working angle of 40 deg, double joints through 80 deg. Rated at 0.41 to 150 hp at 100 rpm, in a size range from $\frac{3}{8}$



to 3 in., they are available either solid or bored. New yoke design has ears of high strength and permits full freedom of movement of the joint. Case-hardened and fine alloy steels provide light weight and durability. Write on company letterhead to Lovejoy Flexible Coupling Co., Dept. MD-1, 4949 W. Lake St., Chicago 44, Ill.



A MOUNTING
Parallel Base



BB MOUNTING
Barrel Bolted



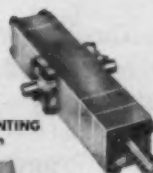
C MOUNTING
Right Angle
Flange
Blank End



D MOUNTING
Right Angle
Flange
Rod End



E MOUNTING
Pivot Tongue



F MOUNTING
Trunnion



HB MOUNTING
Head Bolted

NOPAK

CLASS 7 CYLINDERS

7 Universal Mountings ONE BASIC BODY

This is the only truly modular cylinder that is mass produced, yet gives you all the installation advantages of a custom-built unit. Any stroke length from 1" to 20" is immediately available in bores from $\frac{3}{4}$ " to 3". Pressure rated for 200 p.s.i., air; 1000 p.s.i., oil, in the most popular stroke lengths.

Roll 'em Over!

UNIQUE SQUARE BARREL: Made of seamless extruded, aluminum alloy, drawn to a 16 micro inch finish, hard anodized to assure an extremely durable surface. Life tests reveal no wear in bore after millions of cycles. The four-square flush barrel provides unique and exclusive opportunity for direct bolt-in mounting into any of its sides or longitudinally from either end. (See Mounting HB & BB.)

Bolt 'em!

NO TIE RODS! NO LOCK RINGS! All components including Mounting Attachments neatly contained by only four (4) bolts at each end.

Shine 'em up!

STREAMLINED FLUSH FOUR SQUARE DESIGN — No tie rods; no humps; no bumps, no dirt catching, inaccessible, hard to clean contours.

Hang one on!

MOUNTINGS UNLIMITED: — The 5 Universal Mounting Attachments are quickly bolted to the basic body. In addition, the four-square design allows rotating and inter-mixing these attachments. Now add to this the exclusive Direct Head Bolt and Barrel Bolt Mountings and NOPAK Class 7 becomes the most universal air and hydraulic cylinder ever developed. A natural for even the most difficult applications.

Spin 'em Around!

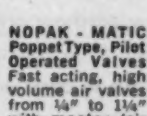
CYLINDER HEADS: — as well as head plate, are precision cast and machined aluminum alloy. The four-square heads can be readily rotated to position ports for most convenient piping. No matter how rotated, the heads align perfectly with the square barrel, resulting in clean, flush surfaces. Heads also provide opportunity for direct bolt-in mounting. (See Mounting HB.)

Other NOPAK "CVA" Products



NOPAK "V" 4-Way, Pilot Operated Slide Valves
Small, compact, 3- and 4-way valves for direct or remote control.

Either single or double air pilot or solenoid actuated. Simple, proven design, durable construction insure trouble-free operation.



NOPAK - MATIC Poppet Type, Pilot Operated Valves
Fast acting, high volume air valves from $\frac{1}{4}$ " to $1\frac{1}{4}$ " with master (air piloted) single or double solenoid. Side or bottom ported sub-plates or manifolds. Removing cover plates affords easy access to piston poppets housed within removable, interchangeable cartridges. 100% J.I.C.

†Patent Pending

*Cylinders, Valves, Accessories. NOPAK offers a complete line of matched Fluid Power components.



NOPAK DIVISION

Galland-Henning Mfg. Co.
2752 S. 31st St., Milwaukee 46, Wis.

DATA SHEETS

DATA SHEETS

DATA SHEETS

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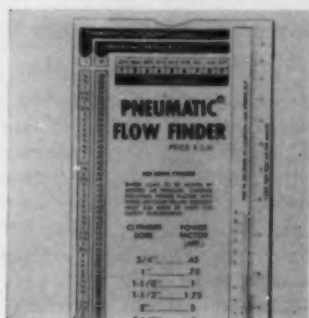
_____ copies of the 1956 Data Sheets

ENGINEERING DEPARTMENT EQUIPMENT

Air-Volume Computer

gives free-air volume for cylinders of any bore, stroke

Flow Finder computer figures standard cubic feet of free air per minute required for any specific job. It gives free-air volume for cylinders of any bore and stroke, at any pressure and time cycle. Finder determines air pressure for desired cyl-



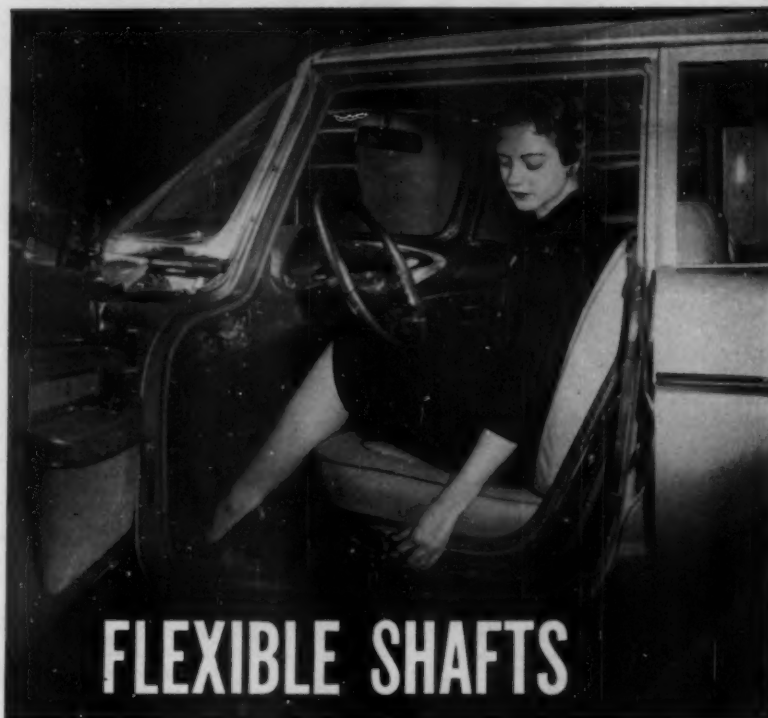
inder stroke speed, matches bore size to required force, tells the minimum compression capacity needed. Flow Finder, Box 578, Westfield, N. J.

Circle 594 on Page 19

X-Y Recorders

has accuracy of ± 0.1 per cent of full scale

Autograf Model 7 X-Y graphic recorder has a large, 30 x 30-in. recording area. Unit combines in one instrument all the facilities needed for rapid, accurate recording of a variety of test measurements involving two variables. Accuracy is better than ± 0.1 per cent of full scale, and maximum pen speed is 20 ips for each axis. Model can be used on a table top, console, or mounted on a wall for maximum readability. Selector switches provide 13 voltage ranges in 1-2-5 sequence from 1 mv per in. to 10 v per in. or 30 mv to 300 v full scale on each axis. Recording mechanism employs dual-drive cables to insure



solve space problems in power seat

Here's why Chrysler Corporation uses flexible shafts in its six-way motion, power operated seat adjuster:

1. **SPACE ECONOMY** ... "flexible shafts provided means to transmit power from a single electric motor, without compromising seat design."
2. **REDUCED STRESSES** ... "flexible shafts act as torsion bars to reduce motor armature stresses induced when the mechanism was stopped or stalled suddenly."
3. **RELIABILITY** ... "not a single shaft fatigue failure reported from the field to date."
4. **LOW COST** ... "flexible shafts definitely represented savings without sacrificing design advantages."

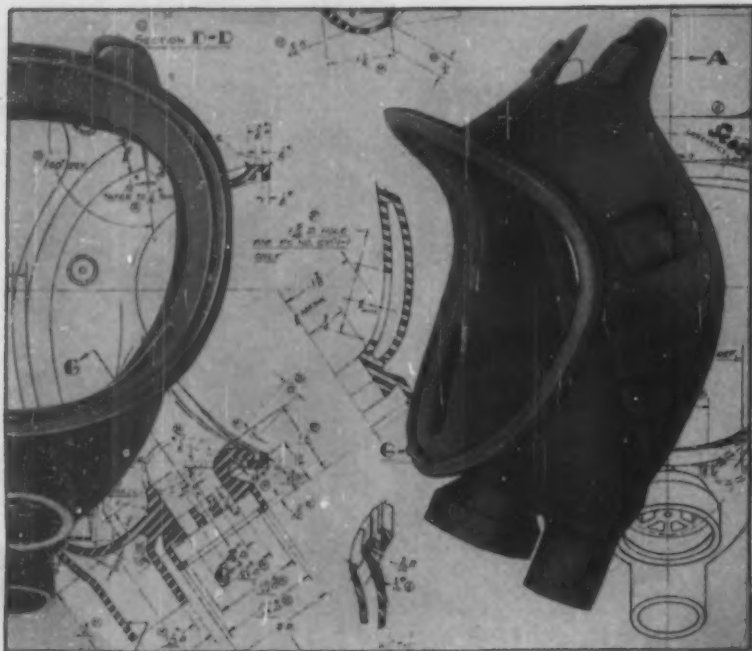
Investigate for yourself how flexible shafts can solve many of your design problems and at the same time reduce costs!

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Courtesy Scott Aviation Corp.

New Molded Profile Reveals Techniques for Better Rubber Specs

In the early stage of planning and design, it was questionable whether this face mask could be molded in rubber—in one piece—practically, yet economically... and here's why.

It calls for an ingeniously designed and machined mold to provide for facial contours, air inlets and outlets, undercuts, feathered edges, valve mounts, fastenings, etc.—one of the hardest-to-fill cavities ever encountered. Also, the rubber must be compounded to flow freely inside this complicated form and still maintain its knitting qualities. How was this accomplished?

While the mask was still in the design stage the customer realized the importance of consulting a rubber specialist. From this conference came an exchange

of suggestions which led to a practical and functional design that permits molding these masks with unusual speed and economy. Here's the idea.

While a job is still on the drawing board consult with rubber specialists. Suggestions can often be made to eliminate high tooling costs or high priced compounds. End results give you better rubber parts, better performance and lowest cost. Regardless of how simple or complex your rubber needs may be call Continental—specialists since 1903.

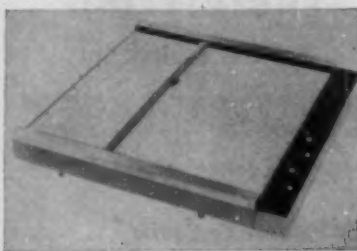
Engineering catalog.

In addition to custom-made parts, Continental offers an extensive line of standard grommets, bushings, bumpers, rings and extruded shapes. Hundreds of these are shown in the No. 100 Engineering Catalog. Send for a copy or refer to it in Sweet's Catalog for Product Designers.

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accurate X and Y alignment. The X and Y servo systems are completely independent in each axis and are isolated from ground. F. L. Moseley Co., 409 N. Fair Oaks Ave., Pasadena, Calif.

Circle 595 on Page 19

Spaced Lettering

for pressure-sensitive layouts

New method to insure accurate spacing between letters is known as Spaced Lettering. Each set contains one size of letters, numbers, and punctuation symbols. Sets are available in Round Gothic face in 96, 48, 24, and 12-pt sizes. Each character is individually die-cut from clear pressure-sensitive acetate for easy application. Lettering is suitable for titles, headings, charts, legends, diazochromes, drawings, and transparencies. It can be reproduced through the diazo or photographic process. Chart-Pak Inc., Leeds, Mass.

Circle 596 on Page 19

Copying Machine

makes permanent copies
9 in. wide by any length

Office Copier 909 uses a Ready-Pak developer cartridge which eliminates the mixing and pouring of chemicals. Cartridge also conserves developer by returning it to an airtight container when the copier is not in use. Unit produces high-contrast, black-on-white copies from



any original to 9 in. wide by any length; it copies all colors. Reproductions are unaffected by heat, light, or humidity. Photostat Corp., 1001 Jefferson Rd., Rochester 3, N. Y.

Circle 597 on Page 19

Laboratory Controller

is a true proportional controller, free of cycling

Brookstat laboratory controller is basically a portable instrument for the precise, automatic regulation of temperature. It is readily applied also to the measurement and control of pressure, vacuum, and liquid level. Unit provides proportional



control (modulated duration pulse), on-off control, high-limit alarm, as well as an output signal for recorders. It is a true proportional controller free of the cycling. Unit handles output loads to 15 amp, 115 v ac. Brooks Instrument Co., Hatfield, Pa.

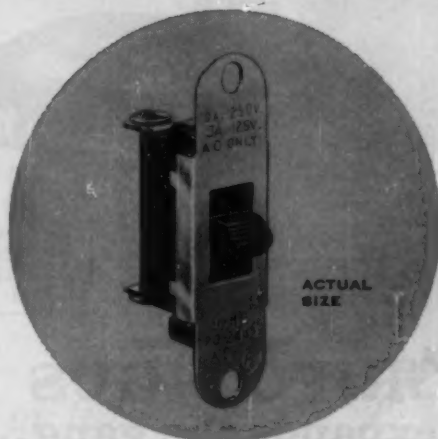
Circle 598 on Page 19

Solid-State Voltmeter

achieves average of 200 readings per sec

Series 5001 digital voltmeter combines proven solid-state reliability and speed with high accuracy and resolution. Automatic range and polarity selection are provided on ranges of ± 1.1999 , ± 11.999 , ± 119.99 and ± 1199.9 v. Average of 200 readings per sec is achieved with a maximum error of ± 0.01 per cent of full scale, \pm one digit. Front-panel switch permits selecting maximum impedance of more than 500 megohms on the low ranges or a constant 10-megohm input impedance on all ranges. Complete

NEW SLIDE SWITCH



PLANNED PERFECTION RUGGED • COMPACT DEPENDABLE

Circle F announces a new, high reliability slide switch. A product of advanced engineering techniques, this new switch features silver alloy contacts and silver plated rockers, with the entire mechanism enclosed in a dust free, Hi-Impact thermosetting plastic case

Slow make — Slow break precision operation
Specially designed non-welding contacts

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The new Switch — SPST — is available with screw terminals or with lugs designed for both soldering and push-on tabs

It offers 2 hole mounting • 10 amp 250V A-C — 15 amp 125V A-C
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P2 (Pilot Projection Type) Four weld projections, eliminating rocking during welding operation and to give a maximum weld.

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- Fast, clean welding—minimum current, short time-cycle.
- High welding quality, low carbon steel construction.
- Optional self-locking feature—the exclusive GRIPCO Toplock.
- Complete range of sizes available for immediate delivery from stock.

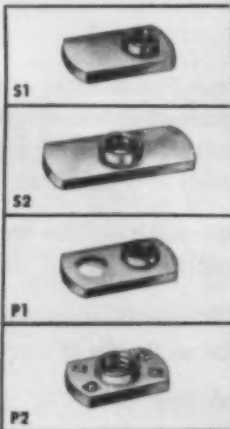
Get the full details on the new GRIPCO Tab Weld Nuts—including data on welding set-ups and complete price information—from your GRIPCO GUS. You'll find him listed in the Yellow Pages under "Bolts & Nuts" as the local GRIPCO Representative.

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ENGINEERING DEPT. EQUIPMENT



facilities for system use are provided. Visual display is visible to 50 ft and at angles to 70 deg in all directions. Electronic Associates Inc., Long Branch, N. J.

Circle 599 on Page 19

Linear Accelerometer

has weight of 4.5 grams

Model AK 106 piezoelectric linear accelerometer is designed for applications requiring accurate measurements of shock and vibration. It has a weight of 4.5 grams, natural frequency of 60 kc, and operates over a range of $\pm 10,000$ g. Sensitivity of the unit is nominal 5 peak mv per peak gram at room temperature. Instrument is encased in stainless steel and operates over a temperature range of -65 to $+250$ F. Statham Instruments Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.

Circle 600 on Page 19

Volt-Ohm Meter

covers frequency spectrum from 20 cps to 700 mc

Model M-201 volt-ohm meter combines the functions of ac voltmeter, dc voltmeter, and ohmmeter in a compact, 13-in., portable unit. Instrument is suited to a wide range of measurement in laboratory, broadcasting, and general testing applications. It has a high dc input impedance of 122 megohms over all ranges, a low input capacitance of approximately 1.5 mmf, and a single ac probe for taking voltage measurements throughout the full frequency range of the instrument. Four leads are provided for all testing functions; four jacks are located in a common area on the front panel for fast connection and operation. Borg-Warner Controls, Div., Borg-Warner Corp., P. O. Box 1679, Santa Ana, Calif.

Circle 601 on Page 19

THE ENGINEER'S Library

Recent Books

Fuel Cells: Power for the Future. By David R. Adams, Pierre-Ives Cathore, Robert E. Gaynor, Robert D. Jackson Jr., John H. Kirsch, Lawrence L. Leonard, George S. Lockwood Jr., W. Paul Warnock, and Russell E. Wilcox Jr.; 160 pages, 8½ by 11 in., paperbound; published by Fuel Cell Research Associates, P. O. Box 157, Cambridge 38, Mass.; \$18.75 per copy.

Primary objective of this study was to determine the commercial and engineering practicality of present and potential fuel cells. This was done by establishing a method of evaluating fuel cell performance (Chap. IV), analyzing existing fuel cell developments (Chap. V), and comparing present and future fuel cells with conventional sources of power in various power applications (Chap. VII and VIII). Secondary objectives were to investigate the status of fuel cell technology, to present the technical operations and limitations of fuel cells (Chap. II), and to investigate the various chemical fuels used in fuel cells (Chap. III). A technical and economic discussion of dc motors is included to complete the fuel cell study (Chap. VI).

International Developments in Heat Transfer: Part II. Thirty-seven contributors; 313 pages, 8½ by 11 in., paperbound, published by The American Society of Mechanical Engineers, 345 East 47th St., New York 17, N. Y.

This volume contains thirty-seven papers presented at the 1961 International Heat Transfer Conference, held at the University of Colorado. The first of two sections covers boiling and burnout, condensation and two-phase flow. Sample topics in this section include two-phase pressure gradient, heat transfer to high pressure superheater steam in an annulus, dropwise condensation of steam, and heat transfer by condensing pure vapors outside inclined tubes. The second section deals with high-speed flows, aspects of external convection, vibrations and pulsating



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flows. Included under this heading are turbulent transfer from isothermal spanwise strips on a flat plate, heat transfer between a flat plate and a pulsating impinging jet, and convection heat transfer from a rotating sphere.

Association Publications

ASHRAE Guide and Data Book, 1961. Edited by Carl H. Flink; 1286 pages, 9 by 11 1/4 in., clothbound; published by American Society of Heating, Refrigeration and Air-Conditioning Engineers; \$12.50 per copy.

This comprehensive work on the fundamentals and equipment of heating, refrigeration and air-conditioning systems is the first of a two volume series. The second volume on applications will appear in 1962. Sixty-seven chapters are grouped in eight sections as follows: 1. Theory. 2. Materials. 3. Load Calculations. 4. System Components. 5. Unitary Refrigeration Equipment. 6. Air-Conditioning Units. 7. Refrigeration Systems. 8. General. Most of the subjects are taken from the former *Heating Ventilating Air Conditioning Guide* and the *Air Conditioning Refrigerating Data Book*. However, extensive revisions were made and twenty-three new chapters added, including thermoelectric cooling, mass transfer, thermal insulation and water vapor barriers, steam-jet refrigeration, and room air conditioners and dehumidifiers.

Government Publications

OTS Technical Reports. Copies of reports listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

TN-D-900. Effects of Changing Stress Amplitude on the Rate of Fatigue-Crack Propagation in Two Aluminum Alloys. By C. Michael Hudson and Herbert F. Hardrath. Langley Research Center; 24 pages, 7 1/4 by 10 1/4 in., paperbound; \$0.75 per copy.

A series of fatigue tests were conducted on 12 in. wide sheet specimens of 2024-T3 and 7075-T6 aluminum alloy to study the effects of a change in stress level on fatigue-crack propagation. In tests in which the specimens were tested at first a low and then a high stress level, crack propagation continued at the expected rate after the change in stress levels.

PB 151102. High Strength Steel Forgings. By H. J. Jennings and F. W. Boulger. Defense Metals Information Center, Battelle Memorial Institute; 62 pages, 5 1/4 by 11 in., paperbound. This report is mainly concerned with forgings made from martensitic steels heat treated to strengths ranging from 240,000 to 300,000 psi. Forging characteristics, design limitations, dimensional tolerances, and quality-control problems are discussed. Data on mechanical properties are also presented.

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- The Ferrous Metals Book, 1961 Edition (196 pp.) \$2
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- DC Motor Control, by J. Ronald Wickey, 1961 (42 pp.) \$1
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- Preventing Fatigue Failures, by F. B. Stulen, H. H. Cummings, W. C. Schulte, 1961 (32 pp.) \$1
- Simplified Vibration Analysis by Mobility and Impedance Methods, by R. P. Thorn & A. H. Church, 1959-1960 (80 pp.) \$2
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- Electronic and Electric Power Supplies (Symposium), 1958 (40 pp.) \$1
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Colin Carmichael

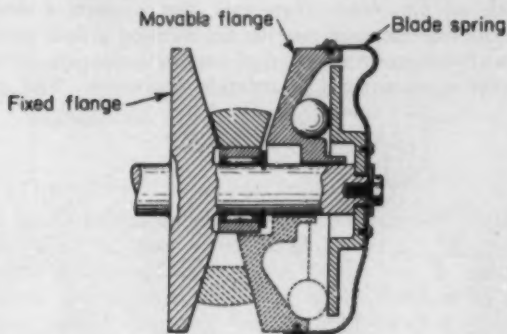
EDITOR

NOTEWORTHY

Patents

Centrifugal Clutch

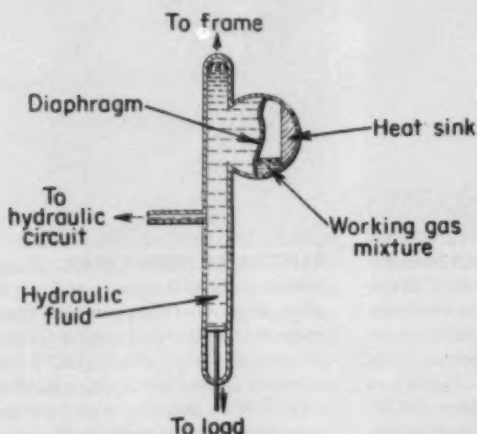
Expanding pulley is engaged with a V-belt at a predetermined speed by balls which roll out along a ramp under centrifugal force. The ramp, formed on the back side of a movable sheave flange, acts as a cam to impart a sliding movement to the flange as the balls



move outward. A blade spring returns the movable flange to the disengaged position when speed is reduced. Patent 2,986,043 assigned to Ateliers de la Motobecane, Societe Anonyme Francaise, Pantin (Seine), France, by Eric Jaulmes.

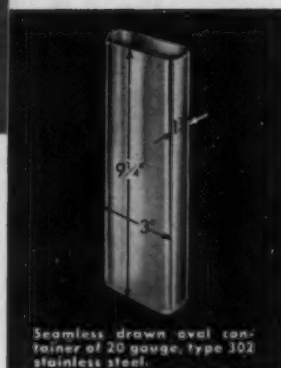
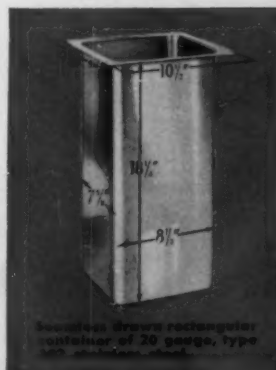
Soft Pneumatic-Spring Suspension

A mixture of a noncondensing gas and a condensing gas is used as the working fluid in pneumatic spring to "soften" the spring action under sudden load changes. In operation, loads are transmitted to a diaphragm type pneumatic chamber by a hydraulic system which is charged to a pressure sufficient to support the dead load on the suspension. The pneumatic chamber contains the working gas mixture under pressure and a



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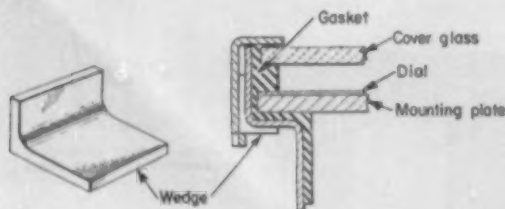
Polar Ware Co.

4500 Lake Shore Road—Sheboygan, Wisconsin

small pool of liquefied condensing gas. Vapor pressure of the condensing gas represents from about 10 to 90 per cent (preferably 20 to 80 per cent) of the chamber pressure. At least 10 per cent of the total pressure is provided by the noncondensing gas to maintain sufficient gas volume for resilient support of the load in the event of complete condensation of the condensing gas. Gas-mixture proportions depend on the required spring softness which is related to the gamma value (γ) of the gas, as defined by: $PV^\gamma = C$ where P = absolute gas pressure, V = gas volume, and C = a constant. The lower the gamma value, the softer the suspension. Patent 2,999,680 assigned to E. I. duPont de Nemours and Co., Wilmington, Del. by Bernhardt J. Eiseman Jr.

Protected Instrument Assembly

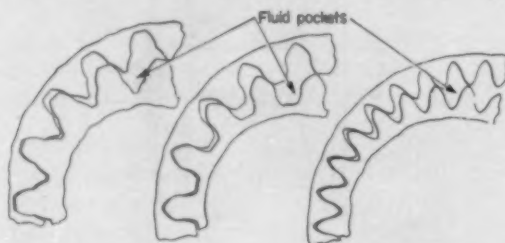
Resilient mounting arrangement for instrument parts provides secure leaktight construction that is protected against severe shock and vibration loads. In assem-



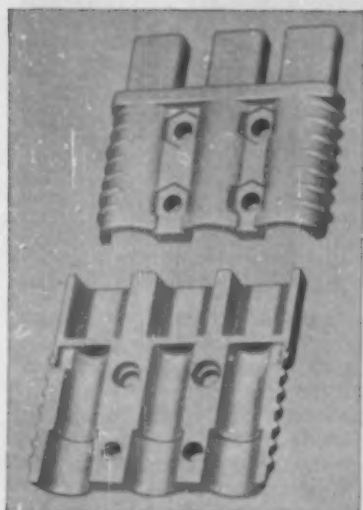
bly, the mounting plate, with its dial, and the cover glass are seated in grooves in an elastomeric, cup-shaped gasket. The gasket is then inserted in the sheet-metal instrument case and a sheet-metal cover member is fitted in place. Elastomeric wedges, which are positioned between the sheet-metal case and cover, engage stamped lug projections on the bottom inner surface of the cover to lock the assembly. In this arrangement, all of the principal parts are isolated from each other by an elastomer section under compression. Patent 2,986,303 assigned to Daystrom Inc., Murray Hill, N. J., by Derek John Dean.

Gear-Pump Gears

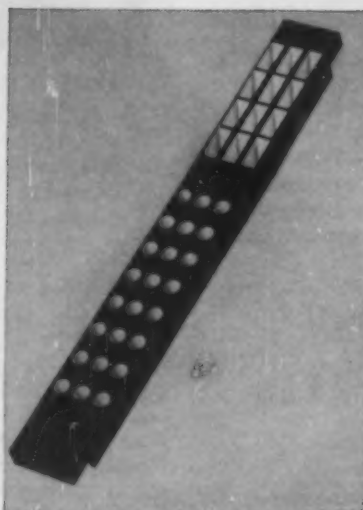
Internal-external gear pairs for gear-pump application have teeth which are contoured to trap fluid in isolated pockets. As the gear teeth begin to mesh, a tooth on the pinion (external) gear contacts a tooth on the internal gear near its tip, forming a fluid pocket with the preceding external-internal tooth pair. This pocket is maintained as rotation continues. The ex-



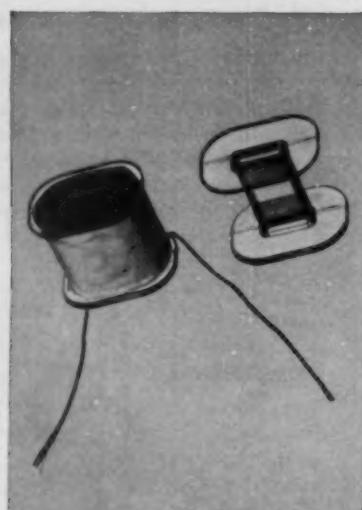
G-E LEXAN® POLYCAR



STRENGTH LEXAN resin has an impact strength of more than 12 foot-pounds per inch of notch — higher than any other plastic! This toughness, plus heat resistance and good electrical properties, make LEXAN resin an outstanding choice for 3-pole connectors used in rugged service on electric trucks.



HEAT STABILITY Lampholder terminal block is used inside electronic equipment where heat is difficult to dissipate. LEXAN polycarbonate resin replaced another thermoplastic which melted under severe thermal conditions. LEXAN has a heat distortion point as high as 290°F. Also keeps high strength in sub-zero cold.

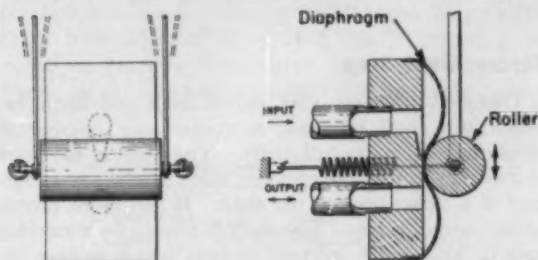


ELECTRICAL PROPERTIES A good dielectric, LEXAN resin is non-corrosive even when used with very fine Class F magnet wire. Coil forms must not distort at temperatures above 200°F under stresses caused by tightly wound wire. LEXAN resin provides high heat distortion temperatures under load.

ternal tooth rides on the flank of the internal tooth, decreasing the volume of the pocket and keeping it isolated from adjacent pockets. The riding action of one tooth on another is smooth, without fouling of the teeth. Patent 2,990,724 assigned to Borg-Warner Corp., Chicago, Ill. by J. Edward C. Anderson and Frederick C. Haberland.

Roller-Actuated Valve

Output flow in a pneumatic valve is controlled by moving a roller back and forth across a diaphragm. The valve consists of a plate which contains two ports and is covered on one side by a flexible diaphragm.

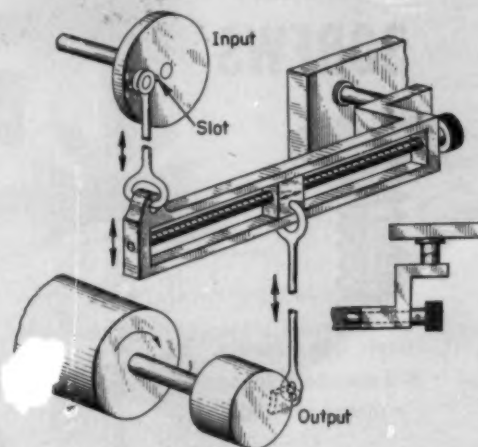


A spring-loaded roller presses the diaphragm against the plate surface, across its full width. With the roller positioned between the ports, flow is cut off. When the roller is moved in either direction to uncover one of the ports, flow is permitted at a rate depending on the exposed port area under the roller.

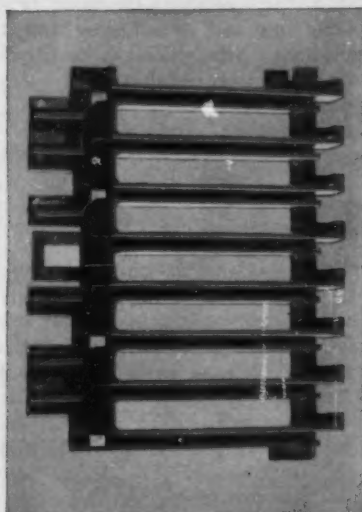
Patent 2,989,076 assigned to Minneapolis-Honeywell Regulator Co., Minneapolis, Minn. by Charles P. Rohmann.

Adjustable Oscillating-Motion Linkage

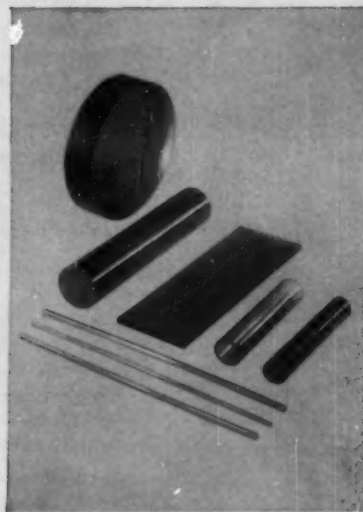
Coarse and fine adjustment of rotary oscillating motion imparted to a shaft is obtained with a double four-bar linkage arrangement. The shaft is driven through a crank by a link attached to a sliding block on the output crank of the driving four-bar linkage.



BONATE RESIN TOUGHEST OF PLASTICS!



DIMENSIONAL STABILITY Card Guide for business machines is molded to close tolerances . . . must undergo minimum change in dimensions during service. Parts show excellent dimensional stability under moist and high temperature conditions. LEXAN resin meets self-extinguishing requirement.



TRANSPARENCY Stock shapes and film of LEXAN polycarbonate resin have excellent transparency. Bar stock is easily machined; film can be thermoformed, heat-sealed and solvent-sealed. Combination of clarity, toughness and malleability gives LEXAN resin the design capabilities of a transparent metal!

LEXAN OPENS UP NEW OPPORTUNITIES...

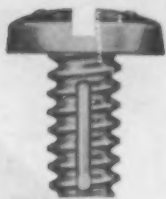
Even before LEXAN entered large-scale production, manufacturers, impressed by its exceptional properties, developed and field tested over 300 applications. G.E. participated in these developments. With the opening of new G-E facilities capable of producing millions of pounds of LEXAN per year, the price of this versatile thermoplastic has dropped dramatically — over 40% in a single year. This fact alone has brought many new products within the range of feasibility. Can you afford to overlook the opportunities presented by LEXAN? Send for details on price, properties, applications and G-E's technical assistance program today! General Electric, Chemical Materials Department, Section MD-11-1, Pittsfield, Mass.

LEXAN®
Polycarbonate Resin

GENERAL ELECTRIC

LONG-LOK®

self-locking TERMINAL STRIP SCREWS



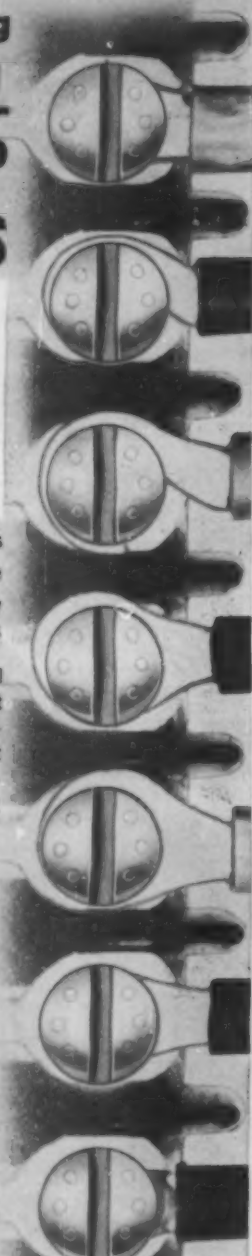
- Eliminate lock washers
- Will not shake loose
- Insure reliability of circuits

These specially developed self-locking screws resist shock and vibration, eliminating the possibility of short circuits due to screws working loose. They will not affect conductivity.

Because they eliminate lock washers, they save weight and speed assembly time.

They are reusable, meet MIL-F-18240 specifications and can be head marked for self-lock identification.

LONG-LOK Self-Locking Terminal Strip Screws are available in all thread sizes and styles. For original equipment installation or overhaul—military or commercial—they provide highest reliability of component and system.



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LONG-LOK EASTERN CORPORATION

68 Urban Ave., Westbury, L. I., N.Y., EDgewood 4-8154

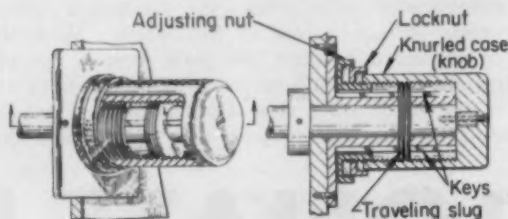
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NOTEWORTHY PATENTS

Position of the block is controlled by a long screw which can be adjusted while the linkage is in motion. The head of the screw is located on the pivot axis of the output crank where the least motion occurs. Input member of the double linkage is a disc which contains a radial slot for attachment of the connecting link. Coarse adjustment of the output motion is obtained by varying the position of the link joint along the slot to alter the effective input-crank radius. Fine adjustments are then made with the screw-block arrangement. Patent 2,997,888 assigned to James Hunter Machine Co., North Adams, Mass. by Edgar C. Rust Jr.

Rotary Limit Stop

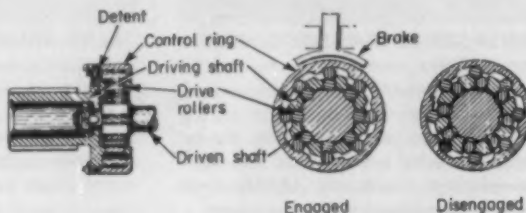
Threaded traveling slug moves back and forth between two limit positions to control the number of revolutions of a control shaft. The slug is mounted to two key tracks on opposite sides of the outer surface of a sleeve around the shaft. It can move linearly but cannot rotate. The shaft is rotated by a knurled case or knob with internal threads which engage ex-



ternal threads on the slug. As the case is turned the threaded slug is driven along its track. Travel of the slug is limited to the distance between the inner face of the closed end of the case and an adjusting nut at the open end. Revolutions of the shaft can be preset to any combination of complete and fractional turns by adjusting the position and length of the nut. Patent 2,998,733 assigned to the United States of America (Secretary of the Army) by Kenneth W. Thompson.

Quick-Release Shaft Coupling

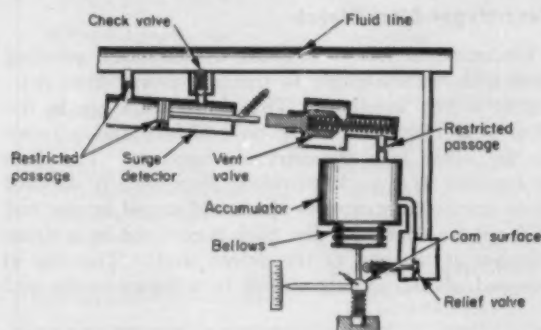
Magnetized rollers serve as the power transmitting elements in a shaft coupling which can be readily disengaged under high-torque loads. In normal operation, rollers carried in a cage at the end of the drive shaft engage mating grooves in the surface of the driven shaft to provide a power connection. The drive rollers are constrained radially by an outer set of rollers which are held in position by a control



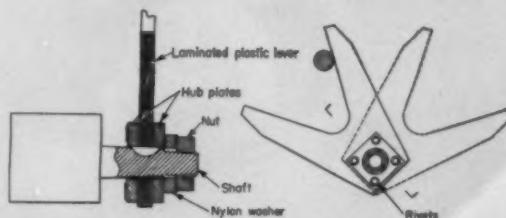
ring. Both sets of rollers are magnetized for adherence. To disengage the coupling, a brake is applied momentarily to the control ring, overcoming the holding action of a detent mechanism to shift the angular position of the ring on the drive shaft. The outer rollers move sideways with the control ring and the inner drive rollers are disengaged from the grooves in the driven shaft by the combined action of magnetic attraction and centrifugal force. Patent 2,989,160 assigned to The Bendix Corp. by Frank Woodruff.

Delayed-Action Pneumatic Control

Pneumatic control system opens a relief valve automatically when a predetermined number of pressure surges have occurred in a fluid line. Increasing or decreasing pressure fluctuations in the fluid line are sensed by a surge-detector cylinder assembly, actu-



ating a spring-loaded piston to momentarily open a vent valve on a pressure-charged accumulator. This action is repeated for each pressure surge in the line. As a result, pressure in the accumulator is gradually reduced, contracting a bellows to raise a cam in incremental steps. After a predetermined number of pressure fluctuations, the cam engages a follower, opening a relief valve to exhaust the fluid line into the accumulator chamber. Patent 2,989,981 assigned to Fairchild Engine and Airplane Corp., Bay Shore, N. Y. by Edward J. Deutsch.



Impact-Resistant Actuating Lever

Operating lever for rotary actuation of a shaft on a limit switch, or similar mechanism, is made of laminated plastic sections for maximum durability under repeated impact loads. Mounted to the tapered shaft with a friction fit, the lever is held in place by a nut and nylon washer. If the friction fit fails, a key pro-

With Eastman 910 Adhesive...

Strong nylon-to-nylon bonds in 10 seconds

Skeptical? We don't blame you. But the fact is that the A. W. Haydon Co. of Waterbury, Conn., is doing just that.

Using a simple jig and a few drops of Eastman 910 Adhesive, Haydon bonds a molded nylon timing gear to a nylon cam. No heat, solvent or excessive pressure is used. Ten seconds later, the unit is ready to be assembled into an automatic telephone switchboard timer.



Eastman 910 Adhesive will form bonds with almost any kind of plastic material (and most other materials).

Still skeptical? Then send \$5 for a trial kit and try it on your toughest job. Kits and further information are available from Armstrong Cork Company, Industrial Adhesives Division, Lancaster, Pa., or Eastman Chemical Products, Inc., Kingsport, Tennessee.

Here are the types of plastic-to-plastic bonds that can be made with Eastman 910 Adhesive Among the stronger: vinyls, polystyrene, phenolics, cellulose, polyesters, polyurethanes and nylon.

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There is no adhesive like Eastman 910 Adhesive

Sets fast—Makes firm bonds in seconds to minutes.

Versatile—Joins virtually any combination of materials.

High strength—Up to 5,000 lbs./in.² depending on the materials being bonded.

Ready to use—No catalyst or mixing necessary.

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The use of Eastman 910 Adhesive is not suggested at temperatures above 175°F., or in the presence of extreme moisture for prolonged periods.

See Sweet's 1961 Product Design File 10d/Ea.

Laminated Plastic PARTS Any Size Simple or Complex



An Example of Synthane You-shaped Versatility

No matter how many laminated plastics parts you need, Synthane Corporation is the place to buy them. We're versatily equipped to do the job—with hundreds of machines, designed especially for handling laminated plastics. Our people have years of experience in tackling any job in quantities from one to a million, in sizes large, small or in between, simple or complicated. This specialization results in complete control from manufacture of material to finished parts.

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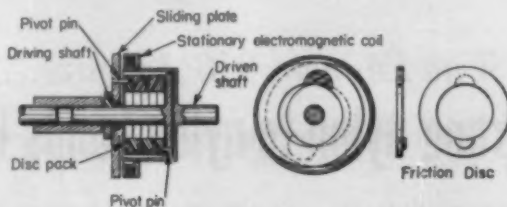
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NOTEWORTHY PATENTS

vides emergency holding action to prolong the connection for a limited number of operating cycles. The lever member consists of several thermosetting plastic sheet sections bonded together by a thermosetting material and sandwiched between two reinforcing hub plates at the shaft end. This construction concentrates the weight around the hub to minimize the moment of inertia, thus reducing resistance to rotary acceleration of the lever and shaft on impact. In addition, when struck at the edges of the laminations, the lever has sufficient resilience to withstand repeated impacts over long periods without failure, yet is rigid enough to rotate the shaft. Patent 2,990,725 assigned to Square D Co., Detroit, Mich. by James D. King.

Centrifugal-Disc Clutch

Electromagnetically actuated clutch uses pivoting discs with friction edges to transmit power from driving to driven members. The clutch discs are in the form of a ring with a lug on one face and a recess on the other face, diametrically opposite. The discs fit together as a pack providing diametrically opposed pivot points on successive discs. Mounted at the end of the drive shaft, the disc pack is enclosed by a drum member at the end of the driven shaft. The disc at one end of the pack is pinned to a flange at the end



of the drive shaft. The disc at the other end of the pack is pinned to a sliding plate which can be rotated slightly with respect to the shaft. To engage the clutch a stationary electromagnetic coil is energized, pulling the sliding plate into engagement with the end of the drum. As the plate slows down, the discs pivot about each other, engaging the drum surface. Patent 2,994,418 assigned to Metron Instrument Co., Denver, Colo., by Frederick K. Floyd, Sanford L. Simons, John P. Mahoney Jr., and Walter Vaughn.

High-vacuum cryogenic pump uses liquid nitrogen and liquid helium to further reduce pressure level obtained with a conventional diffusion or high vacuum pump. The liquid nitrogen enters a jacket around the evacuated chamber, condensing any residual gases such as water vapor, CO₂, and hydrocarbons. Liquid helium, which is at a much lower temperature than the nitrogen, is then poured into an inner container, immediately condensing all of the remaining residual gases except helium and a small amount of hydrogen. Patent 2,985,356 assigned to National Research Corp., Cambridge, Massachusetts, by Norman Beecher.

D.C. Position TRANSDUCER



offers
**COMPACT
INSTALLATION**

G. L. Collins Corporation

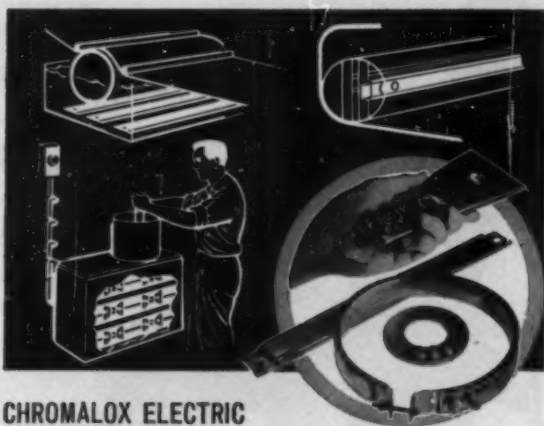
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Circle 370 on Page 19



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VERSATILE, UNIFORM HEAT for your product or process.

Compact, metal-sheathed Chromalox Electric Strip Heaters produce uniform heat, accurate temperatures and long-term service. Low initial cost, low installation costs, low operating costs are other advantages of Chromalox Strip Heaters for heating tanks, platens, ovens, molds, moving parts. 500 standard sizes, shapes, ratings, terminal arrangements available, mostly from stock. Get full details. Send for Catalog 60.

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Circle 371 on Page 19



NEW AIRMATIC® TRIO CONTROL

Contains automatic moisture ejection filter, a piston-type self-relieving regulator and a mist-type lubricator. All anodized aluminum, it assures the best in conditioned air for all pneumatic devices.

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Circle 372 on Page 19

257

Designing a Differential?

STOP!

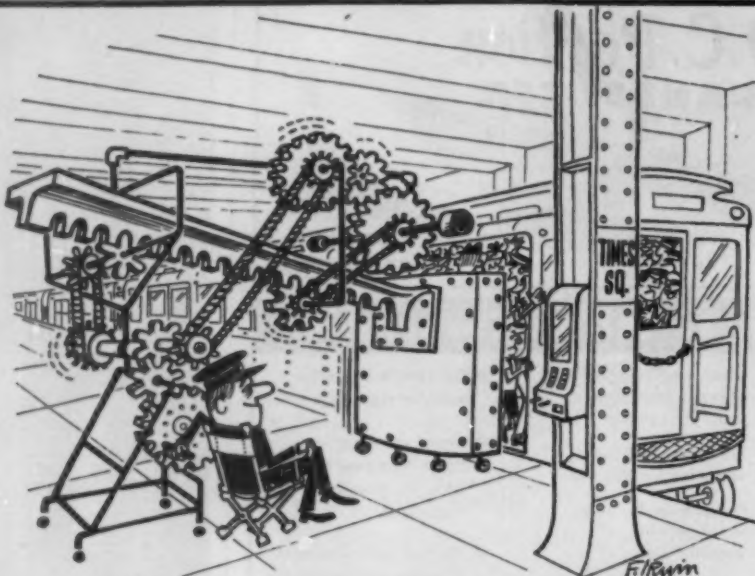
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**PRECISION
CAM ADJUSTMENT
WITH A SCREW DRIVER . . .
IN SECONDS!**

One type cam . . . no special cam lobes required.
Snap Action Switches, N. O. and N. C.—electrically separated

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Complete AIR CONTROL

REGULATOR—FILTER—LUBE

gives an accurate, steady flow of efficiently lubricated and filtered air free of condensate and dirt.

Protects air operating systems and equipment from pressure surges, scoring, rusting and damage due to "dirty" air. Gives trouble free service.

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Refill lubricator without stopping operation or shutting off air.

Compact, combination—easy to install—only 2 connections.

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NEW HEAVY DUTY 7/8" BORE MINIATURE CYLINDERS



Double Acting
and
Spring Return



Maximum Pressure
250 psi AIR — 2500 psi
HYDRAULIC, NON-SHOCK

• Now, a rugged, extra powerful miniature cylinder with all the features desired by designers! Ideal for automation equipment, jigs and fixtures where extra speed and stamina is called for and savings in space, air and cost are necessary. **COMPACT:** space-saving screw-together construction. **INTERNAL CUSHIONS:** of resilient Buna-N reduce shock and noise 80%. **MOUNTS:** Clevis rear, stud front or rear, or foot. **ALL PARTS & SEALS:** replaceable. **PORTS:** standard 1/4" (4PT) on side. **TUBES:** brass. **RODS:** high carbon steel, hard chrome plated. **SHAFT BUSHINGS:** Sintered bronze. **Six STANDARD STROKES** available.

Clippard
Minimatics

Write for NEW BULLETIN NO. 161

Clippard INSTRUMENT LABORATORY, INC.

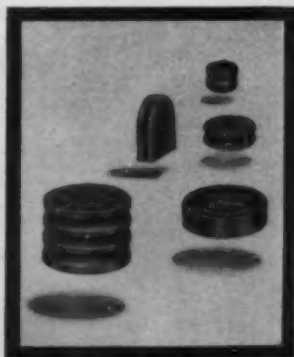
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Circle 376 on Page 19

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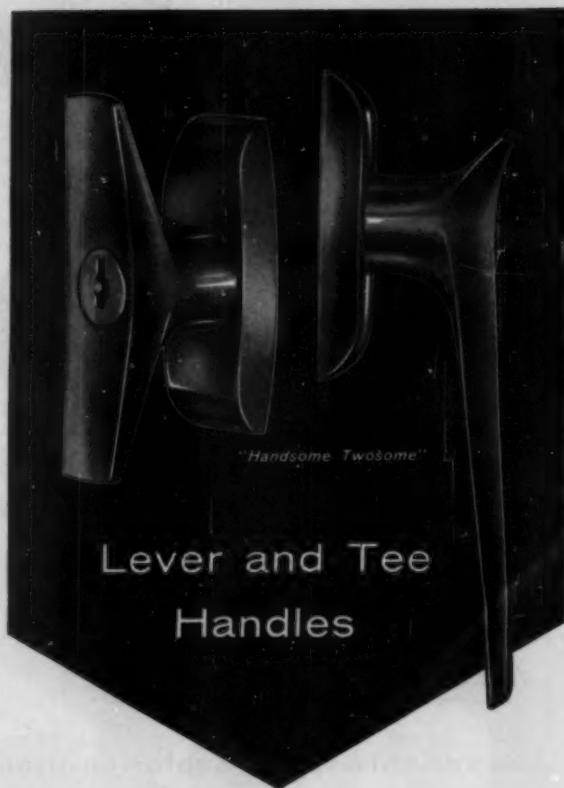
Developing Silicone rubber compounds that embody properties to meet today's product requirements, is a Goshen specialty. GRC-engineered Silicone rubber parts, seals and components have no superior when it comes to resistance to chemicals, acids, extreme temperatures, moisture, weathering, oxidation, ozone and other factors that defeat organic rubbers. That's why they're in increasing demand in today's vital electronic, automotive, aero-space and other industries. Let us know your problem.

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Smartly Designed

By CORBIN, of course — modern as tomorrow. Here's the latest word in Lever and Tee Handle design.

All Handles are pressure-cast. Lustrous satin-chrome finish sets the standard. Other finishes available on special order.

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CORBIN CABINET LOCK DIVISION

THE AMERICAN HARDWARE CORPORATION
NEW BRITAIN, CONNECTICUT

Circle 378 on Page 19



Use variable-speed, explosion-proof GAST AIR MOTORS

Need a compact, low-cost motor for original equipment or plant use applications? *Air may be your answer . . .* using one of these efficient Gast rotary-vane Air Motors. Look at the special advantages they offer you:

1. They're explosion-proof — no sparks, no danger!
2. Low initial cost compared to other motors.
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8. Amazingly light, compact for h.p. delivered.
9. Ball-bearing; almost service-free design.
10. Mechanically simple, neat in appearance.

Gast Air Motors are supplied as original equipment on pneumatic hoists, mixers for paint and chemicals, fans, blowers, fuel hose-reel rewinders, liquid pumps, spooling machines and a host of other products. Used in explosive atmospheres and in "hot" locations to 250° F.

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H.P. at 90 P.S.I., 2000 R.P.M.	0.13	0.57	1.1	2.0	4.0	7.0
Weight, lbs.	1½	6½	8	17	25	45

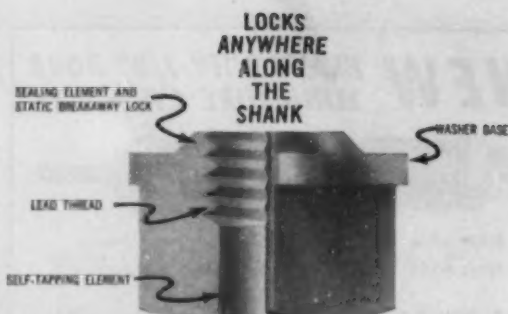
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AIR MOTORS • VACUUM PUMPS • COMPRESSORS

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NEW Nylogrip BRILOK® self locking nuts

New Nylon Bri Lok self-tapping nuts lock at any position along the shank of the screw. As the screw turns into the ruggedly resilient Bri Lok, the material is displaced, and the resulting counter-compressive force causes a tight friction lock. More tightening causes the cone to extrude into the clearance spaces, forming a highly effective seal against liquids, gases, or corrosion.

Advantages: ideal for all applications requiring light weight, high temperature stability, toughness, abrasion resistance and corrosion resistance.

Available in natural nylon and colors, with or without lead thread. For complete information write:



NYLOGRIP PRODUCTS

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Circle 380 on Page 19



AT LAST—A WEDGE-TYPE MACHINE LEVELING JACK THAT LIFTS . . . BUT DOESN'T SHIFT

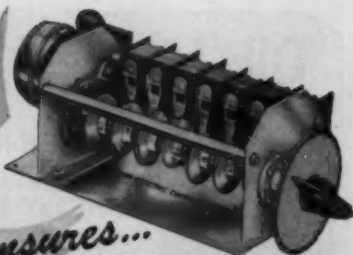
A major advance in precise machine leveling, the new Empco Vertical-Motion Jack gives you the convenience, adjustability and precision of wedge-type leveling—without lateral stress or shifting. Just a simple turn of the hex screw lifts up to 20,000 pounds, easily and precisely—keeps machines performing at their level best! Jack automatically compensates for uneven floors up to five degrees and may be used with anchor bolts where desired.

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*long-lasting accuracy . . .
trouble-free performance in
timing, mixing, compounding,
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Sound, practical design, quality components and precision-controlled assembly insure the long-lasting dependability of ZENITH Multi-Circuit Timers. They are specified as standard components in countless commercial and industrial applications, as well as laboratory equipment and home appliances.

Can be supplied in practically any time cycle and with any number of switches. Available without synchronous motor for elevator control, limit switch, etc.

IMMEDIATE DELIVERY IN ANY QUANTITY . . .
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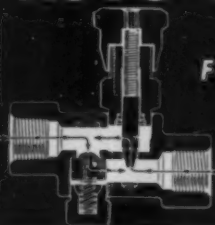
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HYDRAULIC FULL FLOW VALVES



*Flow Control, Needle, Check,
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Model KF Flow Control Valve with Dial and Knob adjustment for direct reading and duplicating reference. Now available in Aluminum for 3000 psi.

Pat. #2,841,174

A complete line: 1/8", 1/4", 3/8", 1/2", and 3/4" female Dryseal Pipe Sizes in all models and types. Equivalent Aeronautical Tube Sizes on special order.

MINIMUM PRESSURE DROP AND POWER LOSS . . . Oversize ports and passages give maximum flow at minimum pressure drop, insure greater accuracy and response in hydraulic or large volume air cylinder control.

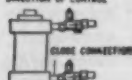
EASY FLOW ADJUSTMENTS under full pressure. Seal located at port to eliminate air or dirt traps. Gland structure equally effective on pressure or vacuum.

SENSITIVE, CHATTERLESS BALL CHECK . . . Patented design insures rapid ball movement to open or close at low differentials.

FORGED BODIES permit higher pressures with wide safety margins. Aluminum—3000 psi; Steel and Stainless Steel—5,000 psi. Pressure ratings based on better than 5 to 1 safety factor. All internal parts are Stainless. Write for illustrated catalog.

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DIRECTION OF CONTROL



Controlling Double
Acting Cylinder

TWO DIRECTION CONTROL



Controlling Single
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Model F Standard
Flow Control Valve
or Model H Needle
Valve



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Dial Flow Control
Valve or Model PH
Needle Valve for
pneumatic mounting



Model C Check Valve
for in-line mounting



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Circle 383 on Page 19

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6028A

Circle 384 on Page 19

261

SPEED SENSITIVE SWITCHES



1 to 6 ELEMENT

SWITCHES

OVERSPEED

One S.P.D.T. switch to trip at speeds between 350 and 6,000 RPM.

OVER AND UNDERSPEEDS

Two S.P.D.T. switches to trip at two different speeds between 300 and 6,000 RPM.

UNDERSPEED

One S.P.D.T. switch to trip at speeds as low as 250 RPM. Maximum operating speed 5,000 RPM.

OVER INTERMEDIATE AND UNDERSPEED

Six S.P.D.T. switches to trip at six different speeds between 300 and 6,000 RPM.

EXPLOSION PROOF AVAILABLE

The switches listed above are available with explosion proof containers that meet all of the specifications of Class I, Group D, explosion proof equipment.

For further information ask for Bulletin 604

SYNCHRO-START PRODUCTS, INC.
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Circle 385 on Page 19

OIL LEVEL GAUGES



- FLUSH-MOUNTING
- DIRECT READING
- HEAVY PATTERN
- EASILY INSTALLED

TYPE 990 AVAILABLE IN 4 STANDARD PRODUCTION SIZES WITH 4", 6", 8" AND 12" LONG SIGHT OPENINGS.

DESIGNED FOR USE ON HYDRAULIC AND LUBRICATING OIL RESERVOIRS AND OTHER LIQUID LEVEL APPLICATIONS.

MODELS AVAILABLE FOR:

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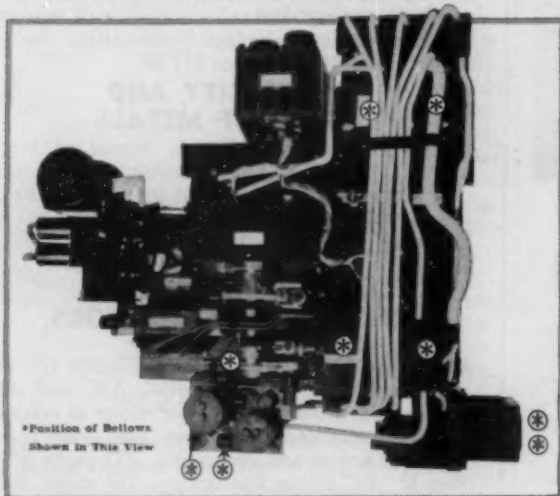
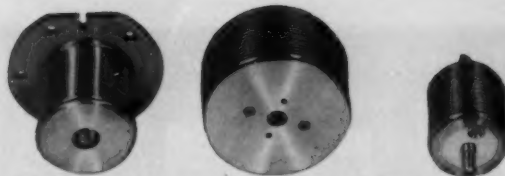
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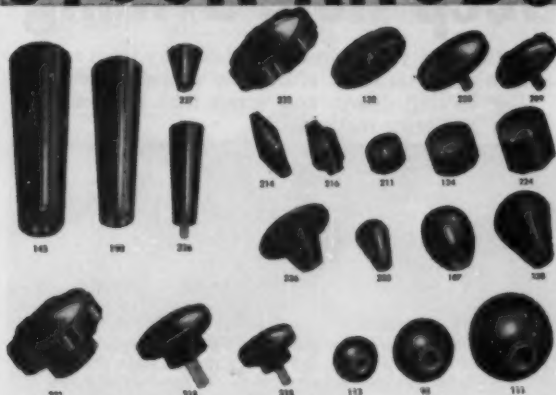
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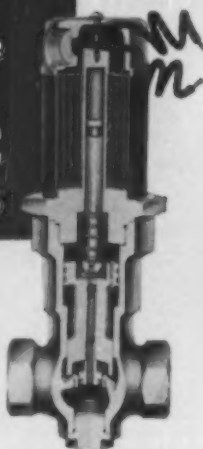
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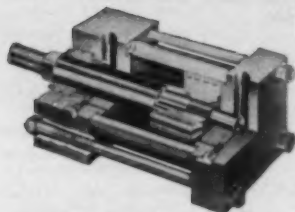
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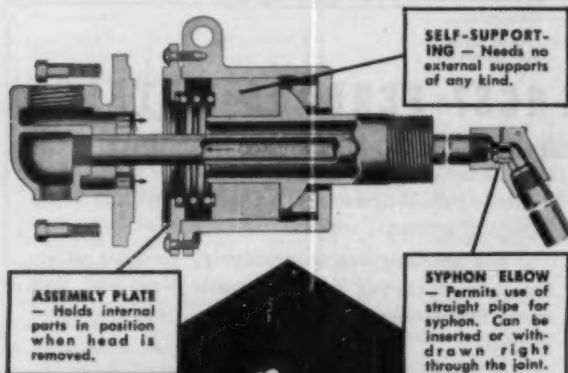
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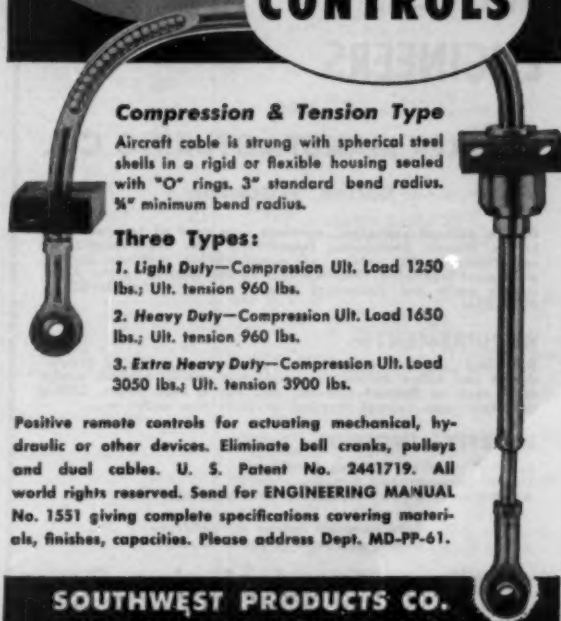
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backtalk—

—A Monumental Miscalculation

In the October 12 edition of this page, we passed along some figures published in a booklet on product life tests by Frigidaire. One item read:

The vane spring in a refrigerator must function nearly 13 trillion times during 20 years of use. In doing this, the spring produces 286 million foot-pounds of energy—enough to lift two diesel locomotives to the top of the Washington monument.

Alvin S. Weiss, project engineer at the Greenwich, Conn., engineering Div. of American Machine & Foundry Co., read this, wrinkled his brow, scratched his head, and whipped out his slide rule. He made some computations then wrote us a letter:

Divide 13 trillion by the number of seconds in 20 years and the result is 20,610 per second. I would therefore assume 13 billion (not trillion) to be the intended value since this would correspond to a compressor motor speed of about 1240 rpm.

We slid our own slide rule around, sent a note to Frigidaire which probably activated yet another slide rule, and received word that "Eagle-eyed Mr. Weiss has indeed caught one of our writers in an error. It should have read billion instead of trillion."

Mr. Weiss also doubts "whether a refrigerator runs much more than 25 per cent of the time, on the average. So," says he, "it looks like we have one diesel locomotive stuck half way up Washington monument."

Since Frigidaire is busy building refrigerators and other things that work much better than some of their slide rules, and since we don't know what to do about locomotives on obelisks, we're just not going to worry about the monument. The way things are in Washington, chances are nobody will notice.

—Research and Resources

You read (Page 108) about the events and persons responsible for failure of a new product. Now somebody else wants to get into the act: The accountant. According to John N. Hart, vice president and controller of B. F. Goodrich Co., "the man who keeps the score on dollars spent for today's research" often influences how these dollars might best be spent in the future.

Whether or not he's right about the wampum watchers having a say about where the dollars

go, Mr. Hart did supply some interesting statistics about money and research:

- More than \$60 billion has been spent on research in the history of the United States, and nearly half of this expenditure has occurred during the last five years.
- In industry, 500,000 scientists, inventors, and technicians are working in research and development today, compared to 70,000 twenty years ago.
- More than 90 per cent of all the scientists who have ever lived are alive today.

—Wanted: A Fitting Fitting

Stanford Research Institute seeks help in a survey it is making for Lockheed Aircraft Corp. on available and potentially available hydraulic fittings suitable for use in missiles and space vehicles. "The principal criterion for selection," says a spokesman, "will be the ability to remain helium-leak-tight even after exposure to the extreme environmental conditions of ground handling, atmospheric boost, suborbital boost, and space. It is our hope that the survey and evaluation will result in the selection of a new fitting to replace the military standard types in rocket-propelled vehicles. We fully realize that a suitable fitting could be currently in use outside of the missile and aircraft industry. Therefore, prior to embarking on a full development program, we want to explore all potential areas of availability."

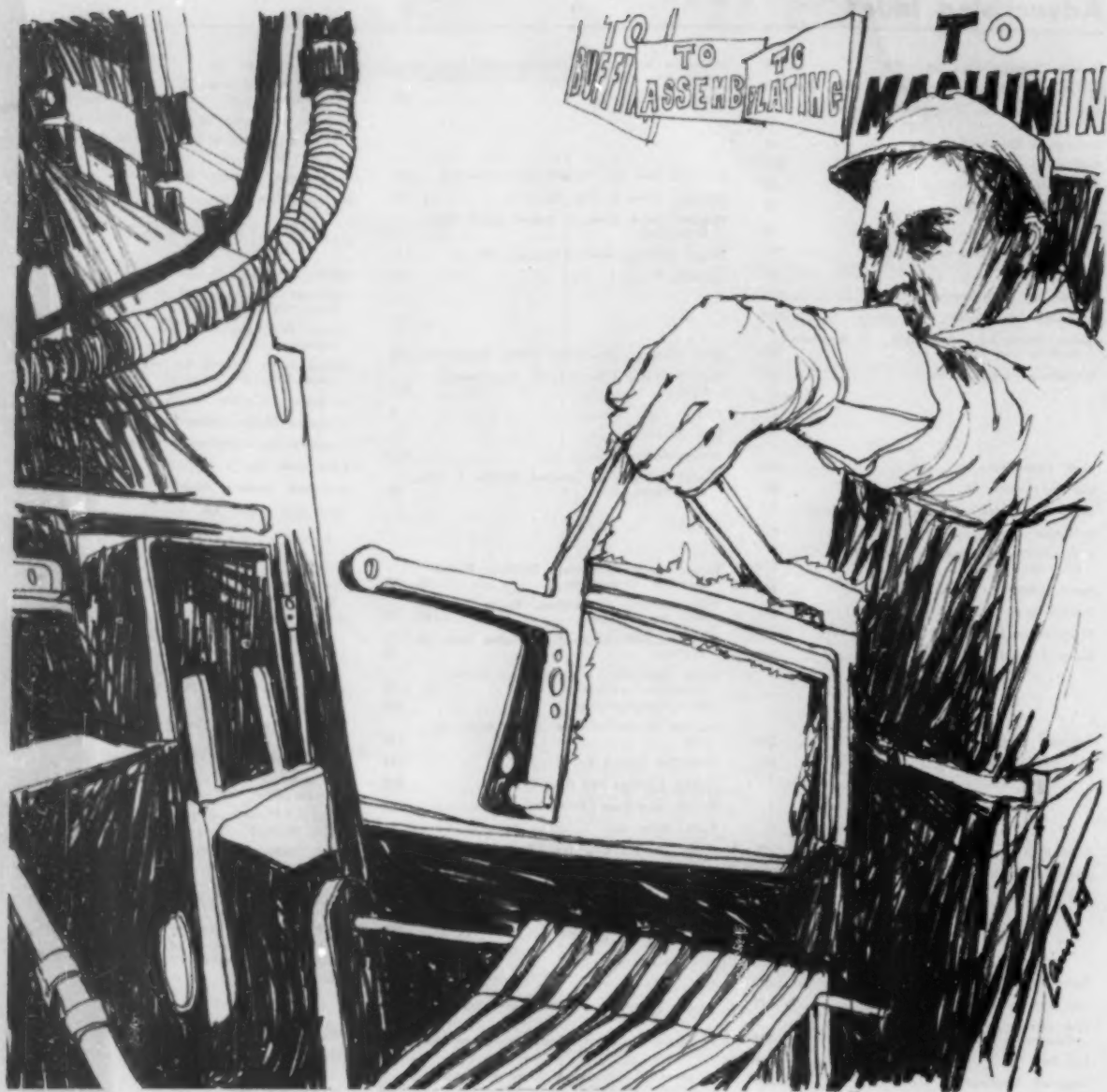
If you know of a fitting that may fit the requirements, write to Adrien J. Altken, Mechanical Engineer, Propulsion Sciences Div., Stanford Research Institute, Menlo Park, Calif.

—Bone of Contention

We recently published a statement to the effect that fabrication of prosthetic devices benefited from the investment casting process. It's the other way around, says Wallace I. Terhune, manager of product research and development for surgical products at the Austenal Co. This company began to make bone-repair and replacement parts 25 years ago; production of such parts led to the development of investment casting.

Now we know. Thank you, Mr. Terhune, for helping us bone up on bones.

269



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30% FASTER MACHINING—Free graphite in its structure makes Graph-Mo machine more easily—30% faster than ordinary tool steels. You save machining time.



OUTWEARS ORDINARY TOOL STEELS 3 TO 1—The free graphite and diamond hard carbides in Graph-Mo's structure work in combination to give longer life to the steel.



PROTECTED BY SPECIAL WRAPPING—Graph-Mo flats are carefully wrapped so that they are delivered in top-notch condition and remain so until you're ready to use them.

Only Graph-Mo® tool steel combines the advantages of machinability, wearability and stability into one steel. It's one of the family of Timken graphitic steels. And Graph-Mo precision ground flats are available in over 250 standard sizes to give you many opportunities to save. For stock list, call your local Timken steel distributor or write to: The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

TIMKEN®
FINE ALLOY STEEL

TIMKEN GRAPHITIC STEELS ARE AVAILABLE FROM STEEL SERVICE CENTERS IN MORE THAN 40 CITIES IN THE UNITED STATES AND CANADA

